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SOCIETY FOR SCIENCE & THE PUBLIC
MAY 26, 2018

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Digging Into the Red Planet

Giant Sloth Chase Scene

The Truth About Web Privacy

DNA Deluge

Consumer genetic testing is hot, but the benefits are spotty

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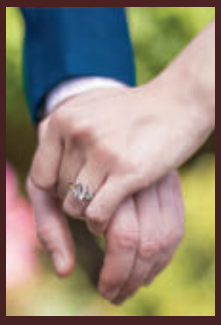

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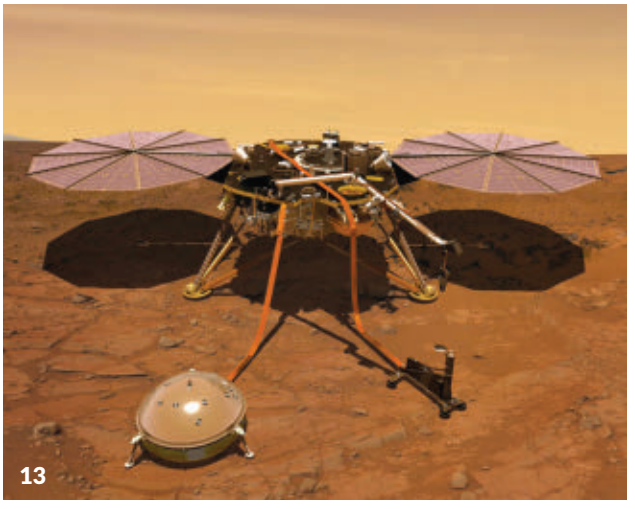
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Departments

COVER Consumer genetic tests may not tell customers that much about themselves. *Daniel Hertzberg*

FROM TOP: PATILA/SHUTTERSTOCK; F. RAMIREZ ROZZI; JPL-CALTECH/NASA

We've got the genes for science journalism

Before visiting my parents for spring break, I thought, "Gee, wouldn't it be fun if I bought them those genetic ancestry kits?" But I never got around to making that purchase, and after reading "An open book," Tina Hesman Saey's cover story in this issue (Page 20), I realize I might have inadvertently made a wise decision.

Consumer DNA test kits have become wildly popular, with millions of people hoping for a peek into their family history, their risk of diseases such as Parkinson's or Alzheimer's, or even a suggestion on what wine will pair well with their genes. While tests like the genetic wine guide are clearly frivolous, others, like those predicting disease risk, can come with consequences.

That's a problem, because, as Saey explains, the science of gene-based prediction is still in its infancy. Scientists don't yet know how to interpret much of the information in a person's genome, let alone apply that to health care. And there are serious privacy issues with sharing one's genetic information, as detectives' use of a genealogy database to find the suspected Golden State Killer revealed in April (*SN Online: 4/29/18*).

Saey's article in this issue is the first of three that dive deep into the science behind direct-to-consumer genetic testing. Saey worked for five months full-time on the series as well as significant prior research and interviews, doing the kind of in-depth reporting on issues important to individuals and society that's core to our mission here at *Science News*. I hope you find the story, as well as Saey's reviews of genetic testing services (Page 28), as thought-provoking as I did.

And though genetic tests might not be so great for predicting the future, it's always good to have a plan. That's why we've been working hard on a strategic plan for the Science News Media Group, which includes *Science News*, *Science News for Students* and the *Science News* in High Schools program.

Our goals haven't changed: to deliver the most accurate, compelling coverage of advances in science, technology and medicine on the planet. We want to give people the tools they need to be critical thinkers and evaluate the news and the world around them, especially in this era of global disinformation.

So we'll continue to cover the news of science as we have for nearly a century, while also tackling new initiatives, including:

- Expand our coverage of the human sciences, including psychology, sociology and economics.
- Experiment with digital tools that let readers control the complexity of an article, so people of all ages and abilities can understand and enjoy science.
- Give people the tools they need to identify misinformation and junk science.
- Undertake a much-needed upgrade of our websites, so that we can deliver high-quality science news to people where and when they want it.

And we'll continue to work to diversify our sources of revenue, so that *Science News* will thrive for at least another 100 years.

Our readers are an opinionated lot, and we love hearing from you. So drop us a line by mail or at editors@sciencenews.org. Thank you for joining us on this adventure! —*Nancy Shute, Editor in Chief*

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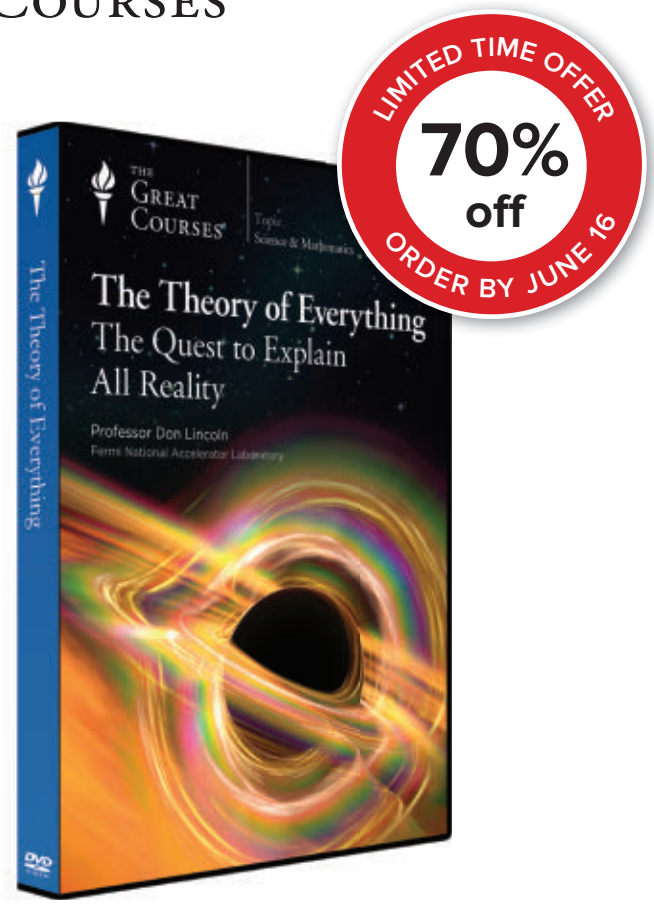

Join the Quest to Explain Everything There Is

At the end of his career, Albert Einstein was pursuing a dream far more ambitious than the theory of relativity. He was trying to find an equation that explained all physical reality—a theory of everything. He failed, but others have taken up the challenge in a remarkable quest that is shedding light on unsuspected secrets of the cosmos.

Experimental physicist and award-winning educator Dr. Don Lincoln of the world-renowned Fermi National Accelerator Laboratory takes you on this exciting journey in **The Theory of Everything: The Quest to Explain All Reality**. Ranging across time and space, and at scales ranging from the subatomic to the cosmic—and even into extra dimensions, with these 24 lectures you will bridge the eras between classical and modern physics and get a glimpse of the goal that has motivated physicists for centuries. It's a dazzling trip!

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Excerpt from the May 25, 1968 issue of *Science News*

50 YEARS AGO

The dwindling dusky

In the marshes around America's spaceport, Kennedy Space Center, live the last few specimens of a bird that may be closer to extinction than even the much-mourned whooping crane. While the whooper might make a gradual comeback if protected and left alone, the dusky seaside sparrow is as good as dead unless man steps in to lend an active hand.

UPDATE: Conservation efforts have kept whooping cranes around. Dusky seaside sparrows (*Ammodramus maritimus nigrescens*) were not so lucky. The population tanked when efforts to flood out mosquitoes breeding near the space center along with construction destroyed the birds' nesting grounds. By 1968, scientists knew of only 17 males. Attempts in the 1980s to breed captive males with females of a different subspecies created a few hybrids. But researchers discontinued the program when the last known dusky, named "Orange Band" for the tag on his leg, died in captivity at the Walt Disney World Resort in 1987.

African giant pouched rats are trained to sniff sputum in the lab and pause at TB-infected samples.

THE SCIENCE LIFE

Rats as TB detectors remain a hard sell

What do land mines and tuberculosis have in common? Both kill people in developing countries — and both can be sniffed out by rodents that grow up to 3 feet, head to tail.

Since 2000, the international nonprofit APOPO has partnered with Tanzania's Sokoine University of Agriculture to train African giant pouched rats (*Cricetomys ansorgei*) to pick up the scent of TNT in land mines. By 2016, the animals had located almost 20,000 land mines in Africa and Southeast Asia.

To help more people, Georgies Mgode, a zoonotic disease scientist at Sokoine, and colleagues began training the rats to recognize tuberculosis, an infectious disease that killed about 1.6 million people in 2016. The most common diagnostic tool — inspection of patients' sputum under a microscope — can miss infections more than half the time. More accurate technologies are costly or still in testing (*SN Online: 2/28/18*).

"Every disease, anything organic, has a smell," says Mgode. *Mycobacterium tuberculosis*, the bacterium that causes TB, emits 13 volatile chemicals that set it apart from other microbes, he and colleagues reported in 2012. Training a rat to be a TB sniffer, recognizing those smells in phlegm, takes about nine months.

The rats get food rewards as they learn to detect land mines or TB in the lab.

To start, trainers bond with 4-week-old rats, naming the pups, playing with them and hand-feeding them. During training, the rats get a food reward when they pause at infected samples. Most trained rats can work through 100 samples in less than 20 minutes, faster than other methods, Mgode says.

Still, convincing others to accept the rats as a diagnostic tool has been a challenge. On April 4 in *Pediatric Research*, Mgode and colleagues made their latest pitch, based on over 55,000 sputum samples from Tanzanian clinics examined by trained rats between 2011 and 2015. Microscopy detected TB in 8,351 samples. The rats detected those, plus 2,745 more, later verified by other methods. The animals did especially well on samples from young kids, who often cough up less phlegm for testing and have low bacterial counts.

Today, the rats screen TB samples from Tanzania and Mozambique, and soon Ethiopia. But the rats have yet to receive global approval from the World Health Organization.

"We are working very hard according to good lab practices, we have well-documented protocols and we are abiding by endorsed techniques," Mgode says. "People [with TB infection] who are being missed in the hospitals are being confirmed by the rats."

— *Yao Hua Law*

BOTH: APOPO

HOW BIZARRE

A practice hole in an ancient cow's head

Ancient surgeons may have practiced dangerous skull-opening procedures on cows before operating on people.

A previously excavated cow skull from a roughly 5,400- to 5,000-year-old settlement in France contains a surgically created hole on the right side, a new study finds. Around the opening, there are no signs of bone healing, which starts several days after an injury. One or more people may have rehearsed surgical techniques on a dead cow, or may have tried unsuccessfully to save a sick cow's life in what would be the oldest known case of veterinary surgery, researchers conclude April 19 in *Scientific Reports*.

Evidence of skull surgery on humans, whether for medical or ritual reasons, goes back about 11,000 years (*SN: 5/28/16, p. 12*). Ancient surgeons needed to know how and where to scrape away bone without harming brain tissue and blood vessels. So practicing bone removal on cows or other animals is plausible.

The ancient cow's skull opening, almost square-shaped and framed by scrape marks, resembles two instances of human skull surgery from around the same time in France, say biological anthropologists Fernando Ramirez Rozzi of CNRS in Montrouge, France, and Alain Froment of Musée de l'Homme in Paris. Microscopic and X-ray analyses found no fractures or splintered bone that would have resulted from goring by another cow's horn. No damage typical of someone having struck the cow's head with a club or other weapon appeared, either. — *Bruce Bower*

A surgical procedure removed the bone missing from the top of this more than 5,000-year-old cow skull (3-D reconstruction), researchers say.

FOR DAILY USE

Browse like everyone's watching

Private Web browsing isn't nearly as private as many people think. Major Web browsers, such as Google's Chrome and Apple's Safari, offer a private browsing option, sometimes known as "incognito." The private window doesn't log activity into the browser's history or influence future autofill recommendations. As such, incognito mode can hide one's activity from others sharing the same device, but that activity is still fair game for the internet itself.

In a new study, 460 people read one of several Web browsers' descriptions of private browsing. The people then answered questions about their privacy expectations of the tool. Respondents expressed significant misconceptions about incognito mode, no matter which browser explanation they read, researchers reported April 26 at the Web Conference in Lyon, France.

More than half thought logging into a Google account through a private window meant Google couldn't record their search history. Not true. About a quarter of participants believed private browsing cloaked their device's unique IP address, which can reveal their location. Also wrong.

Blase Ur, a computer security and privacy researcher at the University of Chicago, and colleagues suggest companies reduce confusion by providing clearer, more explicit explanations of incognito mode and dropping promises of anonymity, such as Opera's assurance that "your secrets are safe" and Firefox's encouragement to "browse like no one's watching." — *Maria Temming*

Take a browsing privacy quiz at **bit.ly/SN_incognito**

SCIENCE STATS

Gaia's latest star map

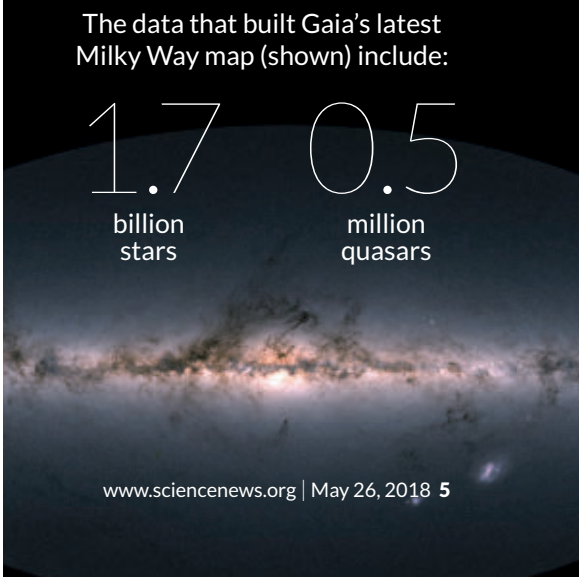
Measuring the position and brightness of nearly 1.7 billion stars, here and in other galaxies, the Gaia spacecraft has created the most precise 3-D map of the Milky Way yet.

On April 25, the European Space Agency's Gaia team released the spacecraft's second batch of data, gathered from July 2014 to May 2016, which was used to create the map. The data also include measurements of half a million quasars — the active black holes at the centers of galaxies outside the Milky Way — and 14,099 known solar system objects (mostly asteroids).

The spacecraft measured the distances and motions of stars by taking advantage of Earth's motion around the sun, a technique called parallax. As Earth moves, stars appear to trace a small ellipse, whose size is related to the stars' distance. Measuring the wavelengths of light the stars emit indicates how fast they are moving toward or away from the sun. Combining Gaia's measurements with earlier sky surveys let astronomers track stars' motions.

Gaia launched in 2013, and released its first batch of data in September 2016 (*SN: 10/15/16, p. 16*). The new data include about 550 million more stars.

"With Gaia, we can reconstruct the whole history of the Milky Way," ESA science director Günther Hasinger said in a news conference on April 25. — *Lisa Grossman*



FROM TOP: F. RAMIREZ ROZZI; GAIA/DPAC/ESA

MATTER & ENERGY

Quantum entanglement goes big

Physicists link up macroscopic, human-made objects

By entangling the vibrations of drumheadlike objects (illustrated), physicists have demonstrated that quantum linkages are possible between human-made structures visible to the naked eye.

BY EMILY CONOVER

Quantum entanglement has left the realm of the utterly minuscule and crossed over to the just plain small. Two teams of researchers report that they have generated ethereal quantum linkages, or entanglement, between pairs of jiggling objects visible with a magnifying glass or even the naked eye — if you have keen vision.

Physicist Mika Sillanpää and colleagues entangled the motion of two vibrating aluminum sheets, each 15 micrometers in diameter — a few times the thickness of spider silk. Physicist Sungkun Hong and colleagues performed a similar feat with 15-micrometer-long beams made of silicon, which expand and contract in width in a section of the beam. The teams report their results in the April 26 *Nature*.

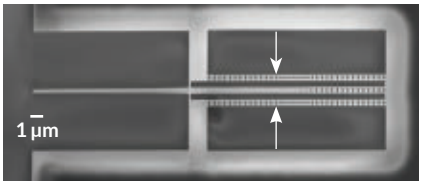
"It's a first demonstration of entanglement over these artificial mechanical systems," says Hong, of the University of Vienna. Previously, scientists had entangled vibrations in two diamonds that were macroscopic. But this is the first time entanglement has been seen in human-designed macroscopic structures, which suggests they might someday become useful tools that can be tailored to meet particular technological requirements.

Entanglement is a strange feature of quantum mechanics, through which two objects' properties become intertwined. Measuring the properties of one object immediately reveals the state of the other, even though the duo may be separated by a large distance (*SN: 8/5/17, p. 14*).

Quantum mechanics' weird rules typically apply to small fry — atoms, electrons and other tiny particles — and not to larger things such as cats, chairs or buildings. But that division leads to a confounding puzzle. "Atoms behave like atoms, and cats behave like cats, and so where is that transition in between?" asks physicist Ben Sussman of the National Research Council of Canada in Ottawa, who was not involved in the research.

Now, scientists are extending the dividing line to cover larger and larger objects. "One of our motivations is to keep on testing how far we can push quantum mechanics," says Sillanpää, of Aalto University in Finland. "There might be some fundamental limit for how big objects can be" and still be quantum.

In Sillanpää's experiment, two tiny aluminum sheets — consisting of about a trillion atoms and just barely visible with the naked eye — vibrate like drumheads and interact with microwaves bouncing back and forth in a cavity. Those microwaves play the role of drum major, causing the two drumheads to sync up, or entangle, their motions. In many previous demonstrations of entanglement, the delicate quantum link is transient. But this one was long-lived, persisting as long as half an hour in experiments, Sillanpää says, and, in theory, even longer. "Our entanglement lasts forever, basically."



Physicists entangled the motions of expanding and contracting silicon beams (arrows) using silicon devices similar to the one shown.

Taking a different tactic, Hong and colleagues demonstrated entanglement with two silicon beams, big enough to be seen with a magnifying glass. Within a region of each beam, in a 1-micrometer-long section composed of about 10 billion atoms, the structure expanded and contracted — as if taking deep breaths in and out — in response to being hit with light. Instead of microwaves, Hong and colleagues' work used infrared light of the wavelength typically transmitted in telecommunications networks made of optical fibers, which means the device could be incorporated into a future quantum internet. "From a technology standpoint, that really is crucial," says John Teufel, a physicist at the National Institute of Standards and Technology in Boulder, Colo., who was not involved with the work.

Scientists could use such vibrating structures within a quantum network to convert quantum information from one type to another, transitioning from particles of light to vibrations, for example. Once constructed, a quantum internet could allow quantum computers to communicate and provide unhackable communication across the globe (*SN: 10/15/16, p. 13*).

The ability to entangle these specially designed structures moves scientists a step closer to that vision. "You can really start to think about building real devices with these things," Sussman says. ■

FROM TOP: PETJA HYTTINEN/AALTO UNIV., OLLI HANHIROVA/ARKH ARCHITECTS; R. RIEDINGER *ET AL*/*NATURE* 2016

HUMANS & SOCIETY

Starbucks habits reflect ancestral ties

In China, the legacy of rice versus wheat farming affects behavior

BY BRUCE BOWER

Deeply ingrained cultural differences in everyday behavior between natives of northern and southern China bubble up while the Chinese sip coffee in Starbucks.

How close people sit and whether they dodge or move chairs blocking aisles reveal whether their cultural roots go back to rice farming or wheat farming, researchers report April 25 in *Science Advances*.

As many as 9,000 years of families working together to cultivate rice paddies in southern China has encouraged a lasting focus on others over self, even among that region's city folk today, say psychologist Thomas Talhelm and colleagues.

That dynamic plays out in cafés. Middle-class city dwellers in southern China who may never have farmed rice often sit with others and show deference by walking around chairs blocking aisles, Talhelm's group says. In northern cities, people more often sit alone and move chairs out of the way. A long history of more individualistic wheat and millet farming in the north has promoted a focus on self over others, the scientists propose.

"Different agricultural legacies have given northern and southern China distinctive cultures of social behavior, even among people who have left farming behind," says Talhelm, of the University of Chicago's Booth School of Business.

A sense of interdependence among residents of southern Chinese cities challenges the idea that urban expansion always results in an individualistic, Westernized outlook, he adds.

The new findings make a good case that "vestiges of agricultural practices can persist for some time," says psychologist Timothy Wilson of the University of Virginia in Charlottesville.

Talhelm's group previously observed similar ways in which thinking styles differ between southern and northern Chinese in lab tests (*SN: 6/14/14, p. 11*). This time around, the team observed nearly 9,000 people in 256 Starbucks and other cafés in six Chinese cities.

On weekdays, about 30 to 35 percent of people in northern wheat regions sat alone, versus about 25 percent of people in southern rice regions.

Other factors, including outside temperature, kind of café (a large chain versus a smaller local one), gender and age, did not explain regional disparities in sitting alone, the team says.

In an experiment, researchers stealthily pushed chairs together to block aisles in some Starbucks in both regions and observed 678 people navigating the traps.

People in a self-oriented culture often try to change a situation to their advantage, whereas people in an others-oriented culture typically change themselves to fit the situation. Consistent with that pattern, only about 6 percent of people in southern cities moved chairs out of the way rather than squeezing through them, versus about 16 percent of the caffeine crowd in the north.

A majority of people throughout China avoided moving chairs blocking their way, Talhelm acknowledges. But cultural differences in this behavior emerged in a setting where it wouldn't be expected — an international coffee chain located in large cities where few customers have any farming experience.

Further research needs to examine whether the extent of one's commitment to, say, self-orientation largely explains preferences for sitting alone or moving a chair, Talhelm says. ■

GABRIEL PRIETO/NATIONAL GEOGRAPHIC

HUMANS & SOCIETY

Mass child sacrifice may be largest in history

A hellishly unprecedented scene — what may be the largest known child sacrifice — has been unearthed on a bluff overlooking Peru's northern shoreline.

Around 550 years ago, members of the Chimú Empire ritually killed and buried at least 140 children, roughly ages 5 to 14, and 200 young llamas. "There are no other examples of child sacrifices anywhere in the world that compare to the magnitude of this Chimú event," says physical anthropologist John Verano of Tulane University in New Orleans. The discovery was announced April 26 by the National Geographic Society, which funded the excavation.

Most of the excavated children (skull of one shown above) and llamas displayed cuts on their breastbones and dislocated ribs indicating that their chests had been sliced open. Three adults buried nearby on the bluff, including two women with head wounds, may have been involved in the sacrifice.

Agricultural crises triggered by repeated flooding might have led Chimú leaders to sacrifice children to their gods, Verano suggests. — *Bruce Bower*

LIFE & EVOLUTION

Ancient toothed fowl pecked like a bird

3-D skull reconstruction offers clues to dinosaur-avian transition

BY CAROLYN GRAMLING

A bird that lived alongside dinosaurs may have preened its feathers like modern birds — despite a full mouth of teeth that let it chomp like a dinosaur.

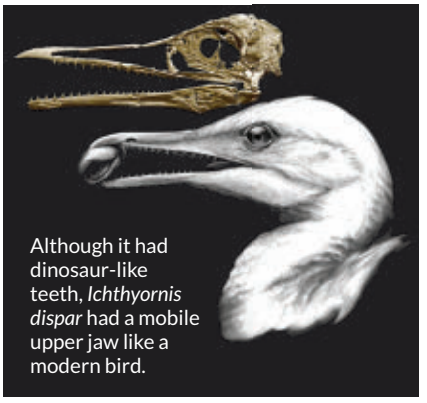
A new 3-D reconstruction of the skull of *Ichthyornis dispar*, which lived 87 million to 82 million years ago during the Late Cretaceous Epoch, reveals that the fowl had a small, primitive beak and a mobile upper jaw. That mobility allowed the bird to use its beak like a modern bird's, researchers report in the May 3 *Nature*. But *I. dispar* also retained the strong jaw muscles and teeth of its nonavian dinosaur ancestors.

"*I. dispar* holds a special place because it was for the longest time one of the only known toothed birds," says Lawrence Witmer, a vertebrate paleontologist at Ohio University in Athens who was not involved in the study. By providing the first in-depth look at the bird's skull, the study offers important new details on the transition from the skin-covered, toothy jaws of dinosaurs to the keratin-covered, toothless beaks of modern birds, Witmer says.

I. dispar was first described almost 150 years ago as a ternlike water bird with a wingspan of about 60 centimeters. Unlike the rather reptilian skull of the dino-bird *Archaeopteryx*, *I. dispar*'s skull looks much more like those of modern birds, says Bhart-Anjan Bhullar, a vertebrate paleontologist at Yale University. But details on *I. dispar*'s features have been lacking; the skulls dug up in the 19th century were smashed in places, Bhullar says.

In 2014, researchers unearthed a nearly perfectly preserved skull. From that fossil, as well as three partial skulls and a reanalysis of the skull discovered 150 years ago, Bhullar and colleagues created a complete 3-D mosaic of the head.

The reconstruction revealed that *I. dispar* had a mobile upper jaw that the bird could raise independently of the lower jaw, as modern birds do. That range of motion allowed the animal to use its tiny beak like tweezers to peck or preen or grasp objects. But the bird also had large holes in the sides of the skull, representing regions where jaw muscles attached. The size of these holes suggests that *I. dispar* had strong jaw muscles, which allowed it to chomp with its teeth to hold food, like nonavian dinosaurs did. "It was pecking like a bird and biting down like a dino," Bhullar says.



Although it had dinosaur-like teeth, *Ichthyornis dispar* had a mobile upper jaw like a modern bird.

MICHAEL HANSON, B.-A. BHULLAR

By measuring the detailed structures of the braincase, the team also concluded that *I. dispar*'s brain resembled modern birds' in many ways. Those similarities include a large forebrain, related to cognitive abilities, and big optic lobes, which process images sent from the eyes. "This thing was thinking like a bird, and had sensitive vision and motor coordination," Bhullar says, suggesting that these adaptations are related to the intense physical requirements for complex flight.

But Luis Chiappe, a vertebrate paleontologist at the Natural History Museum of Los Angeles County, says he is not convinced that braincase size is necessarily related to flight capability, or that the bird's features are representative of the dino-to-bird transition in general. "We have big questions about what was happening with birds in the Late Cretaceous. There is very little known about their skull morphology," Chiappe says. "What we see in *Ichthyornis* might not be representative of an evolutionary trend." ■

EARTH & ENVIRONMENT

Quake linked to geothermal power

Pumping water underground may have rattled South Korea

BY CAROLYN GRAMLING

Injecting fluid into the ground for geothermal power generation may have caused the magnitude 5.5 earthquake that shook part of South Korea on November 15, 2017. The liquid, pumped underground by the Pohang power plant, could have triggered a rupture along a fault zone that was already stressed, two studies suggest.

If the results are confirmed, the Pohang quake would be the largest ever induced by enhanced geothermal systems, or EGS. The technology involves the high-pressure pumping of cold water into the ground to widen existing small fractures in the subsurface, creating paths for the water to circulate and be heated by hot rock. The plant then retrieves the water and converts the heat into power.

Researchers examined local seismic network data for the locations and timing of the main earthquake, six foreshocks and hundreds of aftershocks to determine whether the temblors were related to fluid injections at the Pohang plant. Almost all of the quakes originated just four to six kilometers below surface points that were within a few kilometers of the plant, geologist Kwang-Hee Kim of Pusan National University in South Korea and colleagues report online April 26 in *Science*. These factors, combined with the lack of seismic activity in the region before the injections, suggest that the injections were to blame.

A team of researchers in Europe using the same methodology but analyzing data from regional and international seismic stations came to a similar conclusion in a second paper published online April 26 in *Science*. These findings could be a "game changer" for the geothermal industry, prompting a reevaluation of the dangers associated with EGS, the team wrote.

Other studies have suggested that

induced quakes are closely linked to how much fluid is injected into the ground, whether for fracking, wastewater disposal (*SN: 8/10/13, p. 16*) or EGS. The higher the volume, the stronger the quakes, as fluid injections increase subsurface pressures and make it easier for fractures to slip. The largest known human-induced U.S. earthquake, a magnitude 5.8 temblor in Oklahoma in 2016, was triggered by injecting a total of some 9 million cubic meters of wastewater from oil drilling.

The largest quake previously known to be triggered by EGS was a magnitude 3.4 temblor in Switzerland, one of a series of quakes that ultimately led to the shuttering of a geothermal power plant there.

Researchers initially believed that the injected volumes in South Korea were too small to cause much shaking. The Pohang plant began injecting water in early 2016, putting a total of 12,800 cubic meters into the ground before the 2017 quake. Early quakes were small: Kim and colleagues found that each pulse of injected water was followed by a series of small quakes a few days later. But as the total volume in the subsurface increased with each injection, the quakes grew a bit stronger, suggesting that even a small increase in underground pressure can cause certain faults to rupture, depending on the structure of the fault zones.

The South Korean government is doing its own investigation into whether the 2017 quake was linked to EGS activity, says Stanford University geologist William Ellsworth, a member of an international group advising the investigation. The country sits atop a number of faults. Some research suggests that the magnitude 9 earthquake in Tohoku, Japan, in 2011 may have increased subsurface stress in Korea, causing an uptick in seismicity.

"It's still a vigorous scientific debate," Ellsworth says. "This earthquake provides an unusual opportunity to understand much more about the connection between injections and the triggering of an earthquake." ■

EARTH & ENVIRONMENT

As oceans warm, predators go north

Shark and dolphin migrations could disrupt ecosystems

BY ALLIE WILKINSON

In 2017, scientists spotted bottlenosed dolphins off Vancouver Island following a period of warming. It was the first sighting of the species so far north in Canadian Pacific waters.

L. HALPIN

Far from their usual tropical and temperate waters, some 200 bottlenosed dolphins and about 70 false killer whales were spotted off the western coast of Canada's Vancouver Island in 2017. Over in the Atlantic, bull sharks have turned a North Carolina estuary into a nursery — a sight more familiar in Florida.

Two studies highlight the unusual northern sightings of these three predators. "Alone, these sightings could be seen as accidental, or vagrancies," says marine ecologist Luke Halpin of Halpin Wildlife Research in Vancouver and part of the team that tracked the dolphin sightings. "But we're seeing a lot of warmwater species ranging into historically cold North Pacific waters." Those include pygmy sperm whales and short-finned pilot whales documented by other researchers.

These marine species will increasingly migrate outside of their typical ranges as climate change raises ocean temperatures, scientists say. In just the last century, global average sea surface temperatures climbed by about 0.07 degrees Celsius every decade, though temperature changes can vary widely by location.

The eastern North Pacific had three years of warming from 2013 to 2016. By July 2017, waters about 180 kilometers off Vancouver Island hit 16.5° C. That's in the middle of the range that common bottlenosed dolphins (*Tursiops truncatus*) prefer and at the low end for false killer whales (*Pseudorca crassidens*).

Typically in the eastern North Pacific, bottlenosed dolphins aren't found at latitudes north of Eureka, Calif., and false killer whales don't venture north of Pismo Beach, Calif. But during a routine seabird and marine mammal survey, Halpin spotted a large herd of bottlenosed dolphins and false killer whales. It was the first time either species had been seen in noncoastal waters of the Canadian Pacific, Halpin and colleagues report April 20 in *Marine Biodiversity Records*.

A similar trend is occurring in the Atlantic, with baby bull sharks appearing in increasing numbers every year since 2011 in Pamlico Sound in North Carolina, another research team reports April 16 in *Scientific Reports*. Previously, the northernmost known nursery for bull sharks (*Carcharhinus leucas*) had been Florida's Indian River Lagoon.

But since 2008, water temperatures in Pamlico Sound during early summer, when bull sharks give birth to live young, have exceeded 25° C more than 60 percent of the time. Salinity also slowly increased over the last few decades, to concentrations suitable for young sharks.

As dolphins and sharks move into new areas, the predators could encounter new — and vulnerable — prey species, says marine ecologist Rebecca Selden of Rutgers University in New Brunswick, N.J., who was not involved in either study. Those meetings could "cause some big ecosystem effects," she says. ■

GENES & CELLS

Enzyme tied to cancer gets a close-up

Unraveling telomerase's structure could lead to new therapies

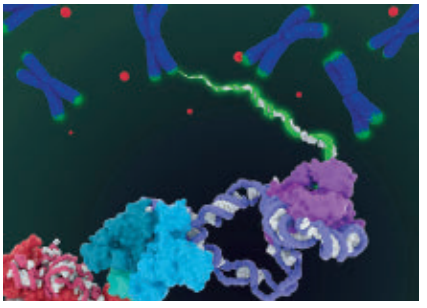
BY AIMEE CUNNINGHAM

Like a genetic handyman, an elusive enzyme deep inside certain cells repairs the tips of chromosomes, which fray as cells divide. It's prized by rapidly dividing cells — tumor cells included — and by scientists on the hunt for cancer therapies.

Now researchers have the best picture yet of this enzyme, called telomerase. Using cryo-electron microscopy, structural biologist Kelly Nguyen and colleagues describe telomerase's structure at a resolution of 0.7 to 0.8 nanometers, three times better than the last attempt.

The close-up reveals how the enzyme's proteins and RNA are put together, potentially offering clues to ways to fight cancer and understand other diseases caused by faulty versions of the enzyme, the team reports online April 25 in *Nature*.

Scientists have pieced together connections between telomerase's activity and cancer, aging and inherited disorders. But the development of therapies has suffered from the lack of a detailed snapshot of the enzyme.



Scientists have gotten a detailed look at telomerase, the two-lobed enzyme (purple and teal blobs) that adds DNA to telomeres (green caps) at the ends of chromosomes (blue X's).

One difficulty is that there is very little of the enzyme in the body. Nguyen, of the University of California, Berkeley, says that she and a colleague "grew thousands and thousands of plates of human cells" to collect enough telomerase to image.

The team's images reveal a two-lobed structure, held together by RNA, Nguyen says. One lobe contains proteins that put all of the pieces of telomerase together and make sure the enzyme gets to the right place in the cell. The other lobe adds DNA to the ends of chromosomes, called telomeres, which are made of repeated DNA stretches. Telomeres lose DNA with each cell division, and telomerase lengthens them again, to protect the chromosomes' genetic information. Along with providing structural support, the RNA guides telomerase as it adds DNA to telomeres.

Any required step in the assembly of telomerase is a potential therapeutic target, says biophysicist Michael Stone of the University of California, Santa Cruz. But to assist in developing cancer treatments, he says, researchers will need to capture telomerase at a resolution of 0.3 to 0.4 nanometers, which will reveal how the enzyme's atoms interact. "The more that you know how the machine is put together, the more you can imagine ways of putting a jam into the machine," Stone says. ■

BODY & BRAIN

First smallpox drug nears U.S. approval

Treatment would counter a bioweapon made from variola virus

BY AIMEE CUNNINGHAM

Amid bioterrorism fears, the first treatment for smallpox is nearing approval.

The drug tecovirimat stops the variola virus, which causes smallpox, from sending out copies of itself and infecting other cells. "If the virus gets ahead of your immune system, you get sick," says Dennis Hruby, chief scientific officer of SIGA Technologies, which helped develop the drug. "If you can slow the virus down, your immune system will get ahead."

An advisory committee to the U.S. Food and Drug Administration recommended May 1 that the agency approve tecovirimat, or TPOXX. The FDA's decision is expected this summer.

Unchecked, smallpox kills about 30 percent of people infected and leaves survivors with scars. Between 300 million and 500 million people died of smallpox in the 20th century before health officials declared the disease eradicated in 1980 after a global vaccination campaign. For research purposes, samples of the virus remain in two locations: one in the United States and one in Russia.

People haven't been routinely vaccinated against smallpox since the '70s. If it reappears, "you need drugs to actually block the progression of the disease," says Grant McFadden, who studies poxviruses at Arizona State University in Tempe.

Fears that the disease, which spreads easily from person to person, could be used as a biological weapon have risen in light of anthrax attacks and other terrorist acts of this century.

Researchers tested how well the drug stops smallpox in animals, while trials to determine the safety and dose of the drug were conducted in people. TPOXX prevented about 90 percent of infected rabbits and monkeys from dying, says SIGA CEO Phil Gomez. Nearly all infected animals that did not receive the drug died.

A smallpox infection does not produce symptoms right away. After 10 to 14 days, a fever and rash occur — that's when a person is most contagious — followed by the formation of pox. TPOXX is meant to be taken at the fever and rash stage.

Two million treatments of TPOXX are already in the U.S. Strategic National Stockpile of drugs and supplies for public health emergencies, Gomez says, a move allowed under emergency preparedness legislation. FDA approval would open the door to studying TPOXX for other uses, assure the supply of the drug and encourage other countries to place the drug in their emergency stocks. ■

JANET IWASA

ATOM & COSMOS

Neutrinos give neutron stars the chills

Fast cooldown hints at what lurks inside the dense stellar objects

BY EMILY CONOVER

For some neutron stars, the quickest way to cool off isn't with a frosty beverage, but with lightweight, subatomic particles called neutrinos.

Scientists have spotted the first solid evidence that some neutron stars, the collapsed remnants of exploded stars, can rapidly cool their cores by emitting neutrinos. The result may lead to a better understanding of the ultradense matter that lies within a neutron star's center.

The new evidence comes from a neutron star that repeatedly gobbled material from a neighboring star. The neutron star rapidly cooled after its meals. X-rays emitted by the neutron star showed that the cooldown rate was consistent with a theorized effect, the direct Urca process, in which neutrinos quickly ferry energy away from a collapsed star, astrophysicist Edward Brown and colleagues report in the May 4 *Physical Review Letters*.

Neutron stars were already known to cool slowly by a similar process that emits neutrinos. But there wasn't clear evidence for faster cooling. The team analyzed observations of the neutron star, located about 35,000 light-years from Earth, as it cooled during a 15-year interlude between feeding sessions. Neutrinos carried away energy about 10 times faster than the rate energy is radiated by our sun's light — or about 100 million times quicker than the slow process, says Brown, of Michigan State University in East Lansing.

Though some other neutron stars have shown hints of a quick chill, "this is basically the first object for which we can see the star actively cooling before our eyes," says astrophysicist James Lattimer of Stony Brook University in New York.

The direct Urca process was named in the 1940s for the now-defunct Urca casino in Rio de Janeiro. "The joke being that this process removes heat from the star the way the casino removes money from tourists' pockets," Brown says.

In the process, neutrons in the star's core convert into protons and emit electrons and antineutrinos (the antimatter partners of neutrinos). Likewise, protons convert into neutrons and emit antielectrons and neutrinos. Because neutrinos and antineutrinos interact very rarely with matter, they can escape the core, taking energy with them. "The neutrino is a thief; it robs energy from the star," says physicist Madappa Prakash of Ohio University in Athens.

The finding may help scientists understand what goes on deep within neutron stars, the cores of which are squeezed to densities far beyond those achievable in labs. The simplest theory holds that the cores are crammed with neutrons and a smaller number of protons and electrons, but scientists have also proposed that the collapsed stars may consist of weird states of matter (*SN: 12/23/17, p. 7*).

The direct Urca process can happen only if the fraction of protons in the center of the neutron star is larger than about 10 percent. So if the process happens, "that already tells us a lot," says astrophysicist Wynn Ho of Haverford College in Pennsylvania. Such observations could eliminate theories that would predict lower amounts of protons.

The team couldn't determine the neutron star's mass, limiting the conclusions that can be drawn. But, Prakash says, if the mass of a quickly cooling neutron star is measured, the neutron star's interior makeup could be nailed down. ■

LIFE & EVOLUTION

Defenseless moths do flying impressions

Clearwing moths may not look all that dangerous, despite having largely see-through wings like bees and wasps. But some of the moths fly like fierce insects best left well alone.

Four clearwing species from Southeast Asia aren't perfect body mimics of local bees and wasps. Yet the resemblance looked much stronger when entomologist Marta Skowron Volponi of the University of Gdansk in Poland and her husband, nature filmmaker Paolo Volponi, spent days at a time poised with a video camera to capture flight patterns. Four clearwing species showed up, including *Heterosphecia pahangensis* (shown at right).

H. pahangensis and two of the other species flew in relatively slow, zigzag paths that resembled the meanderings of local stingless bees that bite. The fourth species flew faster with broader turning sweeps, much like a wasp.

Behaving like something that stings or bites may be an advantage for moths that forgo the cover of night and fly in daylight in easy view of hungry birds and other predators that hunt by sight. Even imperfect body mimics get convincing in the air, Skowron Volponi and colleagues report in the May *Biology Letters*. — *Susan Milius*

M.A. SKOWRON VOLPONI *ET AL/BIOLOGY LETTERS* 2018

MATH & TECHNOLOGY

Recycle this plastic over and over again

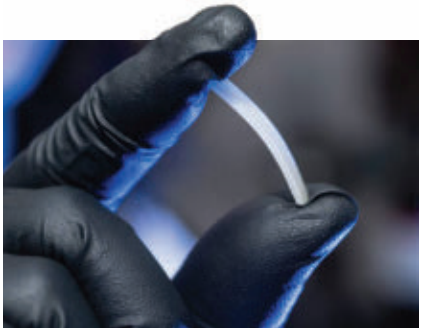
Chemists design a new polymer that is completely reusable

BY LAUREL HAMERS

There's a great future in plastics. A new plastic is able to, when exposed to the right chemicals, break down into the same basic building blocks that it came from and be rebuilt again and again. The material is more durable than previous attempts to create reusable plastic, researchers report in the April 27 *Science*.

Designing plastic that can be easily reused is one line of attack against the plastic waste problem. By one estimate, only about 10 percent of plastic ever made gets recycled. But the material is so cheap and useful that hundreds of millions of tons of it get churned out each year.

A big impediment to recycling is that most plastics degrade into molecules that aren't immediately useful. Transforming the molecules back into plastic or some other product requires many chemical reactions, which makes recycling inefficient. Although biodegradable plastics have become popular, they break down only under certain conditions. More often than not, these plastics end up in landfills or the ocean, unable to fully degrade.



A polymer (shown) that can break down into its original building blocks has the consistency of a disposable plastic bottle.

Designing a plastic polymer that can be broken down into its building blocks and reused without additional processing and purifying is a balancing act, says Michael Shaver, a chemist at the University of Edinburgh who wasn't part of the study. Polymers are long chains of small molecules, called monomers, that link together like beads on a string. Monomers that need extreme temperatures or a lot of chemical coaxing to join up might not be practical building blocks. And resulting polymers need to be stable at high enough temperatures that, say, pouring coffee into a plastic cup won't destabilize the chains and melt the plastic.

Polymer chemist Jianbo Zhu and colleagues at Colorado State University in Fort Collins set out to solve this challenge. The team had created a polymer that could be broken down into its starting molecules. But the resulting plastics were too soft and temperature-sensitive.

Zhu's group modified one of those previous creations, a small ringed molecule, by adding another ring to brace the molecule into a particular conformation. That rigidity helped the monomers quickly link together at room temperature into heat-stable polymer chains.

When exposed to certain chemicals or high enough heat, the polymers degraded back into monomers. The researchers repeated this cycle several times, showing that, in theory, the polymer could be infinitely recyclable.

"This is probably the best system out there," Shaver says.

Still, it's not perfect: Zhu wants to find a way to make the plastic less brittle. ■

ATOM & COSMOS

Fake asteroids buoy water theory

Impacts could have seeded Earth's oceans, lab tests show

BY LISA GROSSMAN

Shooting small rocks from a high-speed cannon reveals that asteroids could have brought water to the early Earth — without all the water boiling away on impact.

It's a theory that's tricky to test. "We can't bring an asteroid to Earth and crash it ... bad things would happen," says planetary geologist R. Terik Daly, who did the research while at Brown University in Providence, R.I. "So we went into the lab and tried to re-create the event as best we can."

After the solar system formed about 4.6 billion years ago, Earth grew up relatively close to the sun, where it was too hot for water to condense out of the gas phase. And Earth was too small to hold onto much nearby gas anyway. So scientists think the planet received its water from somewhere else (*SN: 5/16/15, p. 18*).

Daly, now at Johns Hopkins University, and Brown planetary scientist Peter Schultz made marble-sized pellets of antigorite, a mineral found in the kinds of rocks that may have brought water to Earth. To mimic an impact on a dry planetary surface, the team baked pumice at 850° Celsius, then shot the pellets at the pumice at about 5 kilometers per second using the NASA Ames Vertical Gun Range in California.

That speed is similar to speeds at which asteroids probably crashed into each other during the early solar system, Daly says. In previous computer simulations, all of an asteroid's water would vaporize upon impact at that speed. On early Earth, which lacked an atmosphere, water vapor would have been lost to space.

But some of the water vapor released by the pellets' impacts was captured within melted rock and glass that formed during the collisions. Asteroids could have delivered up to 30 percent of their stored water to growing planets, the scientists conclude April 25 in *Science Advances*.

The next step is to work out how the water could escape from the rocks and glass to create oceans, Daly says.

Planetary scientist Yang Liu of NASA's Jet Propulsion Laboratory in Pasadena, Calif., calls the project "very clever." She says the results may explain how the largely airless moon trapped water and suggest a way for future astronauts to find water there: look near the remnants of impacts. ■

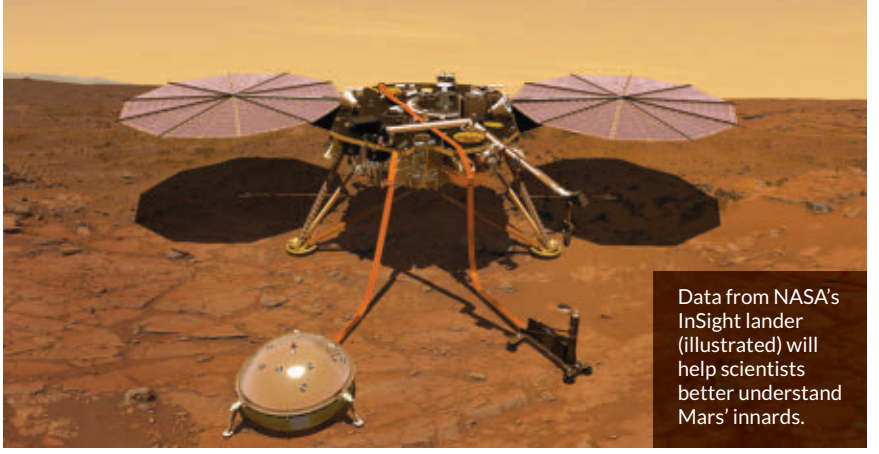
BILL COTTON/COLORADO STATE UNIV.

Watch a simulated asteroid strike at **bit.ly/SN_ImpactTest**

ATOM & COSMOS

Getting the inside scoop on Mars

InSight will use seismic waves to study the planet's interior



Data from NASA's InSight lander (illustrated) will help scientists better understand Mars' innards.

JPL-CALTECH/NASA

BY LISA GROSSMAN

Mars is about to get its first internal checkup. The InSight lander, which launched from Vandenberg Air Force Base in California on May 5, will probe the Red Planet's innards by tracking seismic waves and temperature.

Finding out what Mars' interior is like could help scientists learn how the planet formed 4.6 billion years ago, and how other rocky planets, including Earth, might have formed too. "It's going to fill in some really big holes in our understanding of the universe," says principal investigator Bruce Banerdt, a geophysicist at NASA's Jet Propulsion Laboratory in Pasadena, Calif.

Mars is the perfect planet for this project: It's large enough to be geologically interesting and, like Earth, has a core and mantle beneath its crust. But the Red Planet isn't so large and geologically active that its crust is constantly changing and erasing evidence of the past. "It's kind of the Goldilocks planet," Banerdt says.

> "InSight is one of the first missions really dedicated to exploring the other 99.9999 percent of Mars."
>
> MATTHEW SIEGLER

Assuming it reaches the surface of Mars in November as planned, InSight—short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport—will probe thousands of kilometers below the planet's surface using two main instruments: a seismometer and a heat probe.

The seismometer will measure seismic waves rippling through the planet, similar to the way geologists study Earth's interior (*SN: 9/16/17, p. 11*). These waves move at different speeds through different materials, so tracking the waves can help scientists paint a detailed picture of Mars' insides.

"We have spent a lot of effort scratching at the surface of Mars, but InSight is one of the first missions really dedicated to exploring the other 99.9999 percent of Mars," says Matthew Siegler, a planetary scientist at the Planetary Science Institute who is based in Dallas and isn't part of the InSight team. "We want to know what it is truly made of, not just the thin candy coating."

Thanks to previous measurements of Mars' gravity, astronomers expect to find a metallic core and a relatively dense mantle, but aren't sure how large or dense each layer might be.

Many of Earth's seismic waves are created by earthquakes along tectonic plate boundaries. Mars lacks plate tectonics, but it still has smaller "Marsquakes" triggered by the crust's cooling and contraction. That process releases "little cracks and pops," Banerdt says, which "on a planetary scale are quakes that can shake down buildings."

The seismometer will also sense seismic waves from Martian surface impacts, as well as gravitational tugs from Mars' moon Phobos that periodically make the planet bulge by less than a centimeter. Measuring that bulging may yield information about the size and squishiness of the core, which in turn could help explain why Mars no longer has a magnetic field (*SN Online: 3/27/18*).

In addition to measuring faint ground vibrations, the seismometer is sensitive enough to pick up winds, temperature shifts and leftover magnetism in rocks. InSight's weather station and magnetometer will let the team subtract out signals that don't come from underground. These weather measurements could potentially be used to plan future human missions to Mars (*SN: 1/20/18, p. 22*).

To check Mars' internal temperature, InSight will dig into the surface and measure every half-meter down to five meters. Temperature changes over that small distance will probably be tiny. But they could be used to extrapolate to deeper depths and to calculate how much heat is coming up from inside, revealing how geologically active Mars really is. More heat means more activity.

The spacecraft itself might look familiar: The design was reused from the 2008 Phoenix lander, which found water ice in Mars' polar regions during a five-month mission (*SN: 6/21/08, p. 10*). But InSight has larger solar panels, which should allow it to measure seismic signals for at least one Martian year (about two Earth years). The lander will touch down near Mars' equator to get extra sunlight.

InSight will be the first interplanetary mission to launch from California. After the landing, a robotic arm will pick up each of the instruments and gently place them on the ground over the following month or two. "From then on, we're very quiet. These instruments need to make their measurements in as quiet a situation as possible," Banerdt says. "Nothing much happens after that, except we get great science."

The mission will also test a new way to relay data back to Earth. InSight will carry the first interplanetary CubeSats, a pair of tiny satellites called MarCO that will be dropped off in Mars' orbit. While other existing Mars orbiters will send back much of InSight's information, the lightweight CubeSats will be tested at the task. ■

HUMANS & SOCIETY

Ancient humans hunted giant ground sloths, tracks suggest

People tracking giant sloths thousands of years ago in what is now New Mexico left footprints that indicate humans once hunted the giant creatures, researchers report April 25 in *Science Advances*.

Giant ground sloths vanished from North America about 11,000 years ago, soon after the end of the Ice Age. With their heft and lethal claws, the herbivores would have been formidable prey, says David Bustos, a biologist with the National Park Service at White Sands National Monument in New Mexico.

In 2017, researchers stumbled across more than 100 sloth and human tracks in White Sands. These "ghost tracks" had previously been hidden because they can be seen only under the right moisture conditions.

Sediment tests showed the sloth and human prints were made at the same time. A track analysis also suggested the species were interacting. Bustos and colleagues reconstructed a possible chase scenario: Humans stalked a sloth, or several sloths, which the hunters surrounded in the open. At times, a sloth reared up on its hind legs — perhaps towering over a hunter to fend off an attack.

The encounter "wasn't luck or happenstance; it was cold calculation," says study coauthor Sally Reynolds, a paleoecologist at Bournemouth University in Poole, England. The trail of footprints ends, though, and it's not clear who came out victorious. — *Dan Garisto*

LIFE & EVOLUTION

Cicadas on different schedules somehow mix, mingle and mate

Every few years, a buzz fills the air in the eastern United States as adolescent cicadas crawl out from the soil to molt and make babies. After a childhood spent underground, some species emerge every 13 years, others every 17 years, rarely overlapping. Yet somehow, interbreeding happens between species that should normally be out of sync.

Researchers from the United States and Japan discovered the hybridization while studying cicada genetics. The insects lump into three groups of species that diverged from one another about 3.9 million to 2.5 million years ago. Within each of those groups, species on a 13-year schedule diverged from 17-year-cycle cicadas about 200,000 to 100,000 years ago, the researchers report April 19 in *Communications Biology*.

But the 13-year and 17-year broods within each group share certain genetic information that indicates hybridization. It's possible that neighboring broods swapped DNA when their emergence overlapped — something that happens every 221 years — or if stragglers emerged early or late. — *Helen Thompson*

ATOM & COSMOS

Last year's solar eclipse set off a wave in the upper atmosphere

It was the eclipse felt around the world. The August 21, 2017 total solar eclipse that crossed the United States launched a wave in the upper atmosphere that was detected nearly an hour later in Brazil.

Brian Harding, a space scientist at the University of Illinois at Urbana-Champaign, watched the eclipse from Missouri. But he and colleagues activated a probe near São João do Cariri, Brazil, to observe uncharged particles 250 kilometers high in a part of the atmosphere called the thermosphere.

The probe recorded a fast-moving wave go by half an hour after sunset in São João do Cariri, 55 minutes after the end of the total eclipse, the team reports April 24 in *Geophysical Research Letters*. The wave was produced by the motion of the moon's shadow, which cooled the atmosphere below it. That cold spot acted like a sink, sucking in the warmer air ahead of it and causing a ripple in the atmosphere as the cold spot moved across the globe.

Previous eclipses have caused disturbances at similar altitudes in the ionosphere, the charged plasma of the atmosphere, which overlaps with the electrically neutral thermosphere. But this is the first observation of a wave in the thermosphere. Neutral particles are 100 to 1,000 times denser than plasma in the atmosphere, and it's important to know how they behave too, Harding says. — *Lisa Grossman*

Genetic evidence suggests that cicadas on 13- and 17-year schedules can hybridize.

TEIJI SOTA

GENES & CELLS

Genetically modified plant may boost supply of malaria drugs

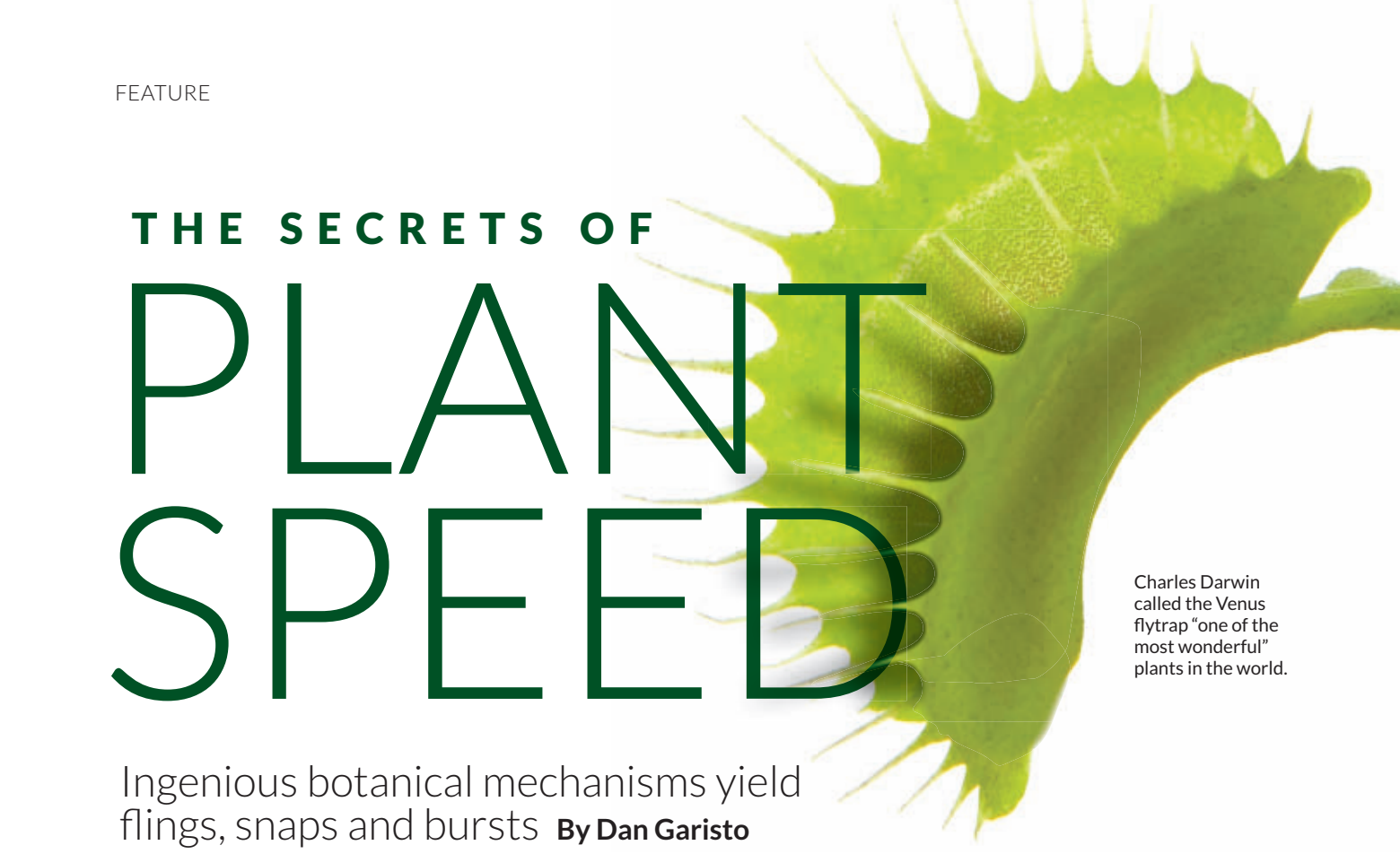
Genetic modifications to a plant that makes artemisinin, a key compound in malaria drugs, more than tripled the amount of the ingredient naturally produced in the plant's leaves.

Previous attempts to genetically engineer *Artemisia annua* to increase the yield of artemisinin failed. So Kexuan Tang, a plant scientist at Shanghai Jiao Tong University, and colleagues deciphered the plant's entire genetic instruction book and identified three genes crucial to artemisinin production. Genetic modifications to increase the activity of these genes boosted the artemisinin level in leaves from 0.1–1 percent of their dry weight to 3.2 percent, the researchers report online April 24 in *Molecular Plant*.

Malaria kills about 440,000 people worldwide every year. The scientists hope to save lives by increasing the global supply of artemisinin, which has been in shortage due to an unstable supply, Tang says. Seeds of the modified plant have been shipped to Madagascar, which grows the most *A. annua* in Africa, as part of a field trial.

Drug companies have used genetically modified yeast to produce semisynthetic artemisinin (*SN: 5/4/13, p. 20*), which is also effective against malaria. But artemisinin from plants is cheaper, says Akhil Vaidya, an immunologist at Drexel University in Philadelphia who was not involved in the research. — *Dan Garisto*

THE SECRETS OF PLANT SPEED



Charles Darwin called the Venus flytrap "one of the most wonderful" plants in the world.

Ingenious botanical mechanisms yield flings, snaps and bursts

By Dan Garisto

The leaves of the Venus flytrap capture prey, like this fly, through a process called snap-buckling. The outer leaf surface expands, building tension until it's too much for the inner surface of the leaf to bear.

Somewhere in the wetlands of South Carolina, a buzzing fly alights on a rosy-pink surface. As the fly explores the strange scenery, it unknowingly brushes a small hair sticking up like a slender sword. Strolling along, the fly accidentally grazes another hair. Suddenly, the pink surface closes in from both sides, snapping shut like a pair of ravenous jaws. The blur of movement lasts only a tenth of a second, but the fly is trapped forever.

"We don't think plants move at all, yet they can move so fast you can't catch them with the naked eye," says Joan Edwards, a botanist at Williams College in Williamstown, Mass.

We tend to picture plants as static life-forms rooted in place until they die. To describe something boring, we say it's "like watching grass grow." But this is a stale view of plant life.

All plants grow, a rather slow form of motion, but many can also move rapidly. The snapping jaws of the Venus flytrap (*Dionaea muscipula*) are the most famous example, but far from the only one. The botanical world offers plenty of equally impressive feats. The explosive sandbox tree (*Hura crepitans*), also known as the dynamite tree, can launch seeds far enough to cross an Olympic-sized swimming pool; sundews (genus *Drosera*) have sticky tendrils that curl around prey; and the touch-me-not (*Mimosa pudica*) folds in its compound leaves within seconds of a touch.

"Plants have evolved a number of different approaches and mechanisms for movement," Edwards says. This variety has resulted in a huge spectrum of plant speed, from the crawl of roots (1 millimeter per hour) to the explosive launch of seeds (tens of meters per second).

The most dynamic plant movements have long entranced researchers.

Fascinated with the Venus flytrap's fast, forceful snap, Charles Darwin called the plant "one of the most wonderful in the world." He performed all manner of flytrap-focused experiments, described in his 1875 book *Insectivorous Plants*. Darwin baited the plants with raw meat, prodded them with objects as fine as human hairs and even tested how the plants' traps reacted to drops of chloroform. Although Darwin didn't fully unlock the flytrap's secrets, he understood that its speed had to do with the geometry of its leaves.

Modern research on rapid plant movement has precision that Darwin would envy. A little over a decade ago, scientists began using high-speed digital cameras and computer modeling to get a new view on plant motion. Frame-by-frame

FROM TOP: JOHAN_R/SHUTTERSTOCK; PATILA/SHUTTERSTOCK

analyses, along with improved resolution, at long last offered a detailed look at the mechanisms that give plants their speed.

Most recently, evidence points to the existence of a startling variety of these mechanisms. In the last few years alone, researchers have discovered contraptions that kick like a soccer player, throw like a lacrosse player and even generate heat to launch seeds explosively.

Nearly 150 years after Darwin's work, the impetus for such research remains the same — a fascination with the movement of plants.

Moving without muscles

Yoël Forterre was a postdoc at Harvard University in the early 2000s when his adviser was given a Venus flytrap as a gift. Never having seen the plant before, Forterre was amazed at its ability to move without muscles. He soon realized that the motion could be understood through the lens of his own specialty: soft matter physics, a field concerned with the mechanics of deformable materials like liquids, foams and some biological tissues.

Forterre published a study in 2005 in *Nature* that was among the first to leverage both high-speed cameras and computer modeling to study mechanisms of rapid plant movement (*SN: 1/29/05, p. 69*).

"The big transformation was digital high-speed cameras," says Dwight Whitaker, an experimental physicist at Pomona College in Claremont, Calif. Around this time, the cameras were making their way into academic labs. "With film, you get one chance," he says. Everything has to be arranged in advance, "which is why directors need to say 'lights, camera, action!' in that order."

With the new technology, Forterre and colleagues could track the tiniest changes in the curvature of the flytrap's leaves, which face each other like two halves of a book. This allowed the team to see *how* the plant's speed relies on the special geometry of those leaves. When the trap is triggered by a fly or other wayward prey, cells on the green outer surfaces of the leaves expand while the pink inner surfaces don't. This creates a tension as the outer surface pushes inward. Eventually, the pressure becomes too great and the leaves, originally convex in shape, rapidly flip to concave, slamming the trap shut in a process known as snap-buckling.

One way of understanding this elastic motion is to look at a popular children's toy, says Zi Chen, an engineer at Dartmouth College who also studies the flytrap. Rubber poppers are little rubber hemispheres that can be inverted. Like a compressed spring, the inverted toys have a lot of potential energy. The poppers convert that energy into kinetic energy as they revert to their original shape, launching several feet into the air. Similarly, potential energy from the tension of the outer surfaces against the inner surfaces of a flytrap's leaves is converted to kinetic energy, allowing the trap to slam shut in about a tenth of a second.

Blasting off

Around the same time Forterre was scrutinizing flytraps, Edwards and her husband were at Lake Superior's Isle Royale, leading a group of budding researchers doing fieldwork on native plants.

As Edwards tells it, a student stuck her head down to sniff a flower of the bunchberry dogwood (*Cornus canadensis*) and announced that "something went poof." Intrigued by this distraction, the team brought specimens back to the lab to capture the behavior on video camera. But whatever triggered the dogwood poof wasn't visible. So Edwards upgraded to a 1,000-frames-per-second camera.

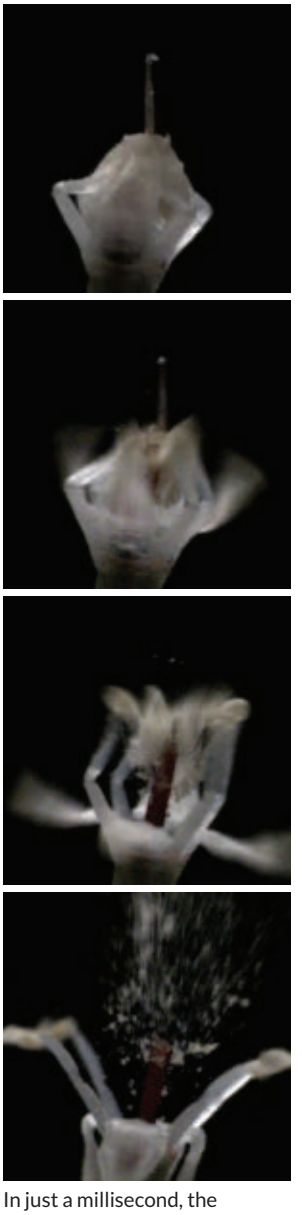
"It was still blurry, so I thought something was wrong with the camera," she says.

She brought the problem to Whitaker, who was then at Williams. It turned out the plant was moving too quickly for the camera to capture. Edwards ordered a special 10,000-frames-per-second camera — then top of the line — and for the first time saw the mechanism clearly (*SN: 6/11/05, p. 381*).

Four petals fused together barely hold down four bent, armlike stamens that protrude from the petals' embrace. When disturbed — by a fat bumblebee or the nose of an inquisitive human — the petals split apart, freeing the stamens. The stamens flip outward, accelerating to a g-force of 2,400, each flinging a pollen sack attached to the tip. (For comparison, fighter pilots can handle a g-force of about 9 before passing out.) This flower trebuchet launches the pollen at whatever triggered the burst, or into the wind.

This early work signaled the start of a now-flourishing research area. High-speed cameras and other high-tech equipment were soon used to study more plants, revealing the secrets of their speed.

Edwards and Whitaker, for example, discovered that, like a detonating nuclear bomb, a peat moss named *Sphagnum affine* explodes into a mushroom cloud. On dry, sunny days, tiny, bloated spore capsules dotting the moss' surface dehydrate, shrinking down and increasing the air pressure within the capsules to several atmospheres. When the pressure becomes too



In just a millisecond, the stamens of the bunchberry dogwood flip outward with a force of 2,400 g's, flinging pollen skyward.

J. EDWARDS ET AL/NATURE 2005

The American dwarf mistletoe, a parasite on the western North American lodgepole pine, is the first plant known to trigger seed dispersal through self-produced heat.

great, a capsule explodes into a cloud of spores. With the help of computer modeling, the duo reported in 2010 that the ominously shaped explosion granted the spores 20 times the height they would otherwise have, boosting their chances of catching a good breeze.

Some plants manage such impressive motion underwater. Bladderworts (genus *Utricularia*) come in aquatic forms, with flowers thrusting up from freshwaters and thin leafy stalks below the surface. The stalks are dotted with traps that are a few millimeters in size and shaped like a sack with a hinged lid. To set a trap, a plant pumps out water from inside the sack, which inverts its sides like a pair of sucked-in cheeks. When prey such as mosquito larvae trigger hairs at the trap's mouth, the lid opens. Water from outside rushes in, pulling in the prey, which is trapped when the lid closes. From open to close, bladderworts can trap prey in about a millisecond.

Water is, in fact, a key player in the most fundamental of plant movements: growth.

"Growth occurs when water moves into a cell and inflates it," says Wendy Kuhn Silk, a biologist at the University of California, Davis. "The speed of most growth responses is determined by the rate of water movement in a tissue."

By moving water from cell to cell, plants can push out their branches and send their roots through the soil or angle their leaves toward the sun. But such movements are only so fast; a Venus flytrap relying on water-driven motion might take 10 seconds to close its trap. It's hard to imagine even the most lethargic fly falling for this kind of slow-motion ambush.

Plants overcome these constraints through mechanical instabilities, created by storing energy through growth. Like the string of a bow pulled until taut, plants can store up potential energy. When the string is pulled too far, or nudged enough, it releases, transforming potential energy into kinetic energy.

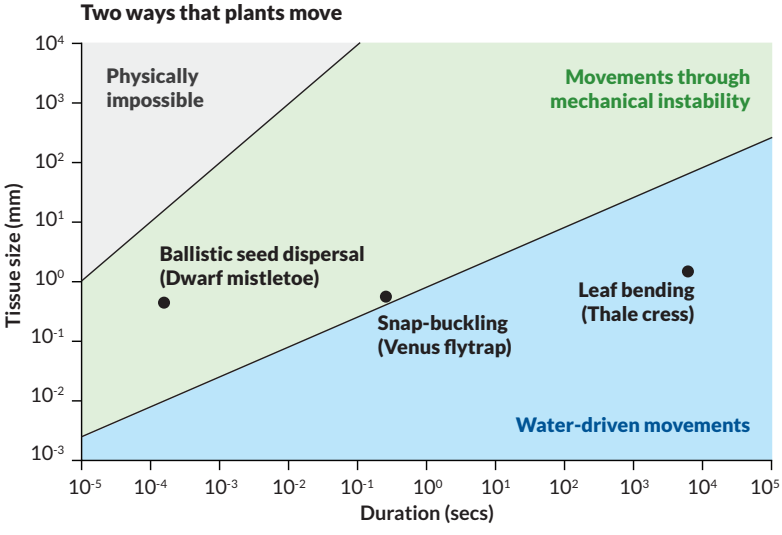
Mechanical instabilities give the flytrap its snap, and even allow some plants to jump. Commonly known as the horsetail plant, *Equisetum* releases microscopic spores shaped like a bendy X. When wet, the legs of *Equisetum* spores curl up. As the spores dry, their legs uncurl. The curling and uncurling that come with humidity changes let the spores skitter around. Sometimes the legs compress before releasing, a forceful kick that sends a spore hopping into the wind.

Myriad mechanisms

The variety of mechanisms has proven as impressive as the speed. To the snap traps and catapults that were the focus of the initial inquiries, in just the last few years researchers have added mechanisms that rely on explosive heat, kicking teeth and lacrosselike flicks. "What we know today is the sheer diversity of it," says Whitaker, before rattling off half a dozen different plant species, all with different mechanisms for rapid movement.

The American dwarf mistletoe (*Arceuthobium americanum*) had long been known to harbor rapid movement. Studies in the 1960s found that the parasitic plant, which grows in bulbous sprigs from the branches of pine trees on the West Coast, could disperse its seeds up to about 20 meters per second. But in 2015, after studying the mistletoe with thermal imaging that could detect minute changes in temperature across areas smaller than a millimeter, researchers reported in *Nature Communications* that the dispersal was triggered by self-produced heat. About a minute before the mistletoe releases its seeds, the plant warms up by roughly 2 degrees Celsius, thanks to a heat-producing reaction in its mitochondria. Like a lit fuse, this reaction triggers a gooey gel in the plant to expand, launching the seeds explosively.

One of the smallest and strangest mechanisms yet discovered was reported this February in the journal *AoB Plants*. Using cameras that can record microscopic movements at 1,000 frames per second, researchers found that the moss *Brachythecium populeum* is a star soccer player that can kick with its "teeth," pliable structures of



Plant hustle As plant structures grow in size, it becomes difficult to move quickly by simply pumping water in and out of cells ("water-driven movements" above). Storing and releasing energy through mechanical instabilities offers a solution, giving flytraps snap and launching mistletoe seeds. SOURCE: J.M. SKOTHEIM AND L. MAHADEVAN/*SCIENCE* 2005

FROM TOP: R.A.J. DEBRUYN *ET AL*/*NATURE COMMUNICATIONS* 2015; C. CHANG

The moss *Brachythecium populeum*, native to the northeastern United States, has reddish-brown spore capsules (one above) topped with pointy structures that bend and warp as they absorb water. As the structures dry (left and middle), they unfurl (right) and release their spores.

tissue that surround the spores. When the plant's microscopic teeth absorb water, they bend and warp. As they dry, the teeth flick outward, lifting the spores to get caught in the wind.

Soon after, in March, researchers described a mechanism similar to how a lacrosse stick flings a ball, in the hairyflower wild petunia (*Ruellia ciliatiflora*). The flower (which despite its name, isn't part of the petunia family) has elongated seedpods. Each pod holds about 20 disk-shaped seeds in hooks. As the seedpod grows, it strains at its seams, which can be weakened by water. When the pod splits in two, the hooks fling the seeds, giving them a dizzying spin of nearly 100,000 revolutions per minute, the researchers reported in the *Journal of the Royal Society Interface.* This spin, which is the fastest yet observed in any plant or animal, keeps the seeds in stable flight.

In search of speed

Despite all these efforts, the physicists, botanists and engineers who have taken part in these studies are still a disparate group. "I wander around, a bit like an outcast," Whitaker admits. Whether it's a biology conference or a physics conference, people are interested but unsure what he's doing there. "This is a very young field."

And there's a lot still to figure out, adds Forterre, now at Aix-Marseille University in Provence, France. The Venus flytrap, extensively studied, still holds mysteries.

Researchers know that an electrical signal is sent to the plant's leaves when a fly brushes the trap's hairs. Somehow, the plant cells expand, resulting in now-understood snap-buckling. But researchers aren't sure what the electrical signal is telling the cells or how exactly the cells expand.

One theory proposes that the electrical signal triggers the release of an acid that weakens the cell walls. Another posits that the electrical signal causes the plant to pump water into the cells of its outer surface, beginning the snap-buckling. Forterre is attempting to use cell pressure probes to settle the dispute, but getting the tool to work in a moving plant is easier said than done.

Researchers are also keen to understand how plants evolved their myriad movement methods. For a lot of plants, the "why" is fairly clear: Plants that can quickly capture insects get a good source of nutrients — nitrogen and phosphorus — that the plants might not be able to get in abundance from the soil. Similarly, plants that move quickly may disperse their seeds farther, gaining an evolutionary advantage over those that don't.

But understanding how the speed came to be is much trickier. A recent clue might help piece together the evolutionary story of bladderworts. In a 2017 overview published in *Scientific Reports*, Anna Westermeier reported something intriguing: one species that had the architecture of the trap, but did not open or close.

This species appears to be a more primitive form in which a trap developed but did not become fully functional, according to Westermeier, of the University of Freiburg in Germany. Identifying relatives that have pieces of mechanisms could help reveal how rapid motions evolved. Whitaker is hoping to find similar potential clues by looking more broadly at plants in the family Acanthaceae, which includes the hairyflower wild petunia and thousands of other species of flowering plants, nearly all of which have some form of explosive seed dispersal.

The great diversity so far uncovered is impressive, but is it unexpected?

"It's not surprising at all," says Karl Niklas, a plant expert at Cornell University. Niklas has studied plant evolution for over four decades. "It's human ego," he says, dismissing the idea that animal movement is anything special. "And I think plants will be around a lot longer than we will." ■

Explore more

- Yoël Forterre *et al*. "Physics of rapid movements in plants." *Europhysics News*. January-February 2016.

F. GALLENMÜLLER *ET AL/AOB PLANTS* 2018

An open book

The stories your DNA can tell are riddled with blank pages

By Tina Hesman Saey

Science News reporter Tina Hesman Saey had a lot of info to make sense of after getting her DNA tested by eight different companies.

MATTHEW RAKOLA

In Nevada, 40,000 people are stepping up to the cutting edge of precision medicine. They are getting their DNA deciphered by the testing company Helix. The idea of the Healthy Nevada project is to link genetic and medical data with information about the environment to get a clearer picture of all the factors that influence health. The free tests are going like hot cakes.

When the Healthy Nevada project launched a similar partnership with 23andMe in 2016, 5,000 residents were offered a free testing kit in exchange for participation in the program.

"Within 24 hours, 5,000 people had broken our website and signed up really enthusiastically," says project head Joseph Grzymski, a computational biologist at the Desert Research Institute's Reno campus. Another 5,000 kits were offered up. "Within 24 hours that sold out," Grzymski says, "and we had 4,000 people on a waiting list."

Even without an invitation or a free deal, consumers are flocking to these tests. Last year, more than 7 million people, mostly in the United States, sent their DNA to testing companies, according to industry estimates.

"DNA testing is no longer a niche interest, it's a mass consumer market, with millions of people wanting to experience the emotionally powerful, life-affirming discoveries that can come from simply spitting in a tube," Howard Hochhauser, interim chief executive of the online geneaology testing company Ancestry, said in a public statement about the company's 2017 holiday sales.

I am one of those 7 million who wanted a read on my DNA, to learn about myself and my heritage. And I went all out. My DNA is now part of the data banks of consumer genetic testing companies Ancestry, 23andMe, Family Tree DNA, Gencove, Genos, Helix, Living DNA and Veritas Genetics. (For a review of my experiences, see Page 28). I learned some things about myself — and about the glaring limits of today's consumer genetic tests.

Broad business

Companies claim that they can read nearly everything about a person in his or her DNA profile. Some firms use DNA details to trace family trees or offer dietary advice and training regimens for burning fat or building muscle. Others go further out on a limb, claiming that testing a handful of genes can reveal a child's future potential.

Need help choosing a wine? A test of variants in a few genes associated with taste and smell — along with a quick quiz — offers options that one company says will please your palate. There are even kits that claim to reveal superhero abilities, or that let two friends virtually mash up their DNA to see what their offspring might look like.

While some applications are clearly frivolous or pure entertainment, others are serious medical business. Consumers can buy tests that screen for gene variants that increase risk for developing cancer, high cholesterol, diabetes, Alzheimer's disease or Parkinson's. Human Longevity, in San Diego, pairs a readout of a person's whole genome with extensive body imaging, blood tests and other medical screening to gauge a client's health with the goal of increasing life span. Scientists say it's probably going to take this sort of comprehensive information to really personalize medicine, but few people can afford Human Longevity's $25,000 price tag.

These companies are part of a growing trend often called personalized, or precision, medicine. Health care systems, including national systems in Estonia, Finland, England and elsewhere, are adding DNA data to medical records, hoping to better tailor treatments to individual patients or even prevent illness. Consumer testing companies draw on databases compiled from such publicly funded research resources to make predictions about a customer's health.

Some testing companies share their data with researchers who study human health and genetics, some do their own studies and some use the data as a revenue source, selling it to pharmaceutical companies. I opted to allow the companies to share my data with researchers. You don't have to choose that option, but I like the idea of contributing to science.

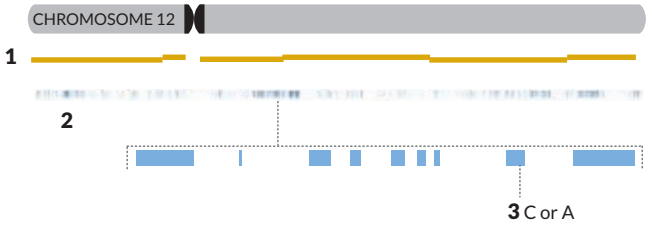
Genetic testing goes mainstream

This feature launches a series across three magazine issues on consumer genetic testing.

For digital extras, including video, a blog and interactives, visit *bit.ly/SN_DNAdeluge*

How much gets tested?

All DNA tests are not created equal. What you learn about your genetic makeup depends on the company you choose and the level of testing it does. Consumer tests fall into three main categories:



1. The whole shebang (almost)

In theory, whole genome sequencing captures all of the 6 billion DNA bases in the genome. In reality, some regions are still a mystery (zooming in on the gold bars under chromosome 12 above would show testing gaps where the bars are staggered). Whole genome sequencing does not detect large chunks of missing, duplicated or rearranged DNA. Still, this approach, offered by Veritas Genetics and others, gives the most comprehensive view of the gene variants a person carries.

2. Focus on the proteins

Exome sequencing analyzes only the protein-coding genes, or the exome, which is about 1 to 2 percent of a person's DNA (blue, above). Exome sequencing generally doesn't provide information about variants that may help regulate gene activity but are outside the genes themselves, nor does it include noncoding genes, which produce some important molecules. Genos and Helix offer exome sequencing. Helix also reads some of the DNA surrounding protein-coding genes.

3. The minimalist approach

SNP (pronounced "snip") chips spot-check variations of single DNA building blocks, known as single nucleotide polymorphisms, sprinkled through your DNA. Where most people have an A, for example, a minority may have a C. SNP chips, or genotyping arrays, detect a preset collection of SNPs that are known to be involved in certain traits. 23andMe, Ancestry and many others rely on these SNP spot-checks.

And more research is needed. Scientists still haven't really learned how to interpret the story in a person's genetic instruction book, or genome, and apply it to an individual's health care. Every researcher I talked to says that goal is far in the future.

"There will be a time when many more common health conditions will have tests you can do that will really inform you," says Bryce Mendelsohn, a medical geneticist at the University of California, San Francisco. "But it will be years, *years*, decades before we're really at that stage."

In August, Mendelsohn opened the Preventive Genomics Clinic at UCSF's Benioff Children's Hospital. There, he counsels adults on what type of genetic testing is right for them, and what to expect from the results. He's not against consumer genetic testing, but he tells his patients that it's for entertainment purposes only.

"If they say, 'I want to know about my ancestry. I want to know how much Neandertal I have,' I say, 'Great, that's what consumer genetic testing is for.' "

But for medically relevant information — such as genetic variants that increase risk for cancer, high cholesterol or heart problems — Mendelsohn orders tests from labs that are certified to make thorough clinical diagnoses. And he makes sure his patients know what to expect and what their results mean.

"It's not that companies that are selling tests are somehow evil," Mendelsohn says; they just promise too much. "I just tell people up front, if you're going to get this test, the odds are that you're going to come back with nothing."

False security

Daniel Cressman, a commercial real estate broker in San Francisco, wasn't expecting to get any troubling or surprising results when he decided to have his DNA deciphered. He did it "just out of curiosity" after attending a conference on future trends. He wanted to be on the leading edge of what he sees as the wave of the future. One day soon, he predicts, "You'll go to the doctor and the first thing they'll do is pull up your genome."

After hearing about the different levels of genetic testing that are offered (see "How much gets tested?" on this page), Cressman decided he wanted the thorough approach: whole genome sequencing. To have his full genetic instruction book deciphered, rather than only certain parts, he looked into various companies' offerings and ultimately settled on Veritas Genetics. The company will sequence a person's genome for $999. Other companies offer whole genome sequencing, too, but for a higher price tag, anywhere from $1,295 for genealogy purposes to health testing ranging from $2,500 to more than $25,000.

Some of Cressman's family and friends are not on board with genetic testing, he says. "Some people ask, 'What if you discover something you don't want to know?' " But Cressman thinks it's usually better to know what's potentially in store. "If I'm flying San Francisco to New York on an Airbus and there's a crack in the wing, I'd kind of like to know before I get on the plane." He didn't discover any cracks in his genes that would cause him or his doctor concern. "Nothing popped out at all," he says.

GRAPHIC: E. OTWELL; SOURCE: VERITAS GENETICS, GENOS

Like Cressman's, my DNA's story, based on Veritas' whole genome sequencing, turned out to be pretty boring. For both of us, testing didn't turn up any variations embedded in our DNA that are likely to cause us to develop a genetic disease. That's good news, says clinical medical geneticist Gail Jarvik. "We tell people, 'If you're lucky, you have a boring genome. That's what you really want.' "

But just because Veritas didn't find anything scary in our genomes, doesn't mean Cressman and I won't develop health problems. Getting a clean bill of health based on your genes "can be very misleading and falsely reassuring," says Jarvik, who heads the division of medical genetics at the University of Washington in Seattle. It can also be a bit of a letdown for people who expect revelations.

I admit to wanting more. Maybe I should have known better, but I thought I'd find out about all the ways I differ from other people, those genetic quirks that make me, me. I was most excited to learn about one weird thing: why my face flushes flaming red and I itch all over when I have even a few sips of alcohol. The companies advertised that they could reveal the genetic reason behind the annoying reaction. When the results came back, I was baffled. 23andMe and Veritas both said that I am unlikely to flush when I take a drink.

But those companies based their erroneous assertion on a variant known to be associated with alcohol-flushing in East Asians. My background is European, so it's unlikely that I would have that variant in the first place. I might have a different variant in that same gene or in some other gene related to how my body processes alcohol. Neither company reports on the other genes. So maybe I was expecting too much. But maybe that's not entirely my fault.

"I think [consumers are] being overpromised that getting the genome sequenced will tell them lots of things that it won't," Jarvik says. "I've definitely run across people who have ... been very disappointed because they didn't learn as much as they thought."

No drama

Most healthy people who send off their cheek swabs or saliva samples for DNA testing should expect to have a boring genome, says Leslie Biesecker, a molecular and clinical geneticist at the National Institutes of Health in Bethesda, Md. At this stage of the science, genome sequencing is not very useful for most people, he says.

DNA sequencing does play a role in diagnosing mysterious inherited diseases and for detecting the mutations that lead to cancer, Biesecker says. But he's dubious of the value for healthy people. "If you don't have such a condition, there's a much lower chance of finding something that would be useful to you medically."

Only a very few people may have a rare genetic disorder and not know it, Biesecker says. "Occasionally we pick up some really severe stuff — hearing loss, cancer susceptibility or severe heart conditions — that you do need to do something about," he says. "We've had several people with a pretty high susceptibility to colon cancer, and we know it will add 10 to 20 years to their life expectancy if they get annual colonoscopies. So for those people, it's clear, it's dramatic and it's useful." But such powerful results are the exception.

Roughly 3 percent of healthy people have known disease-causing variants in one or more of 59 genes on a list compiled by the American College of Medical Genetics and Genomics, according to a 2015 report in *Genetics in Medicine*. Variants in those genes are considered "medically

Traits that tickle

A lot of what you can learn from consumer genetic testing is more useful for dinner party banter than health decisions. A few favorites:

Photic sneeze reflex — Some people sneeze when they suddenly encounter bright light. At least 54 genetic variants scattered among multiple chromosomes help control the sun-stoked achoo.

Ear fold — How prominent the rim on the outer edge of the ear is depends in part on a variant of the *EDAR* gene. The gene is important for skin, ear, eye and hair development.

Cilantro preference — Some people like cilantro, others say it tastes soapy. Studies have linked some genetic variants to liking or disliking the herb.

Big toe or not? — Some people have longer second toes than big toes. At least 35 genetic variants, plus the balance of estrogen and testosterone in the womb, help determine toe (and finger) length.

Sweet or salty — Preference for salty or sweet snacks is influenced by at least 43 genetic variants, some located in or near genes involved in brain development.

Asparagus odor in urine — A variant near the *OR2M7* gene influences whether people can smell asparagus in their urine after eating the vegetable.

Smelling the roses — Some people can detect a specific rose scent chemical, thanks to an *OR5A1* receptor gene variant.

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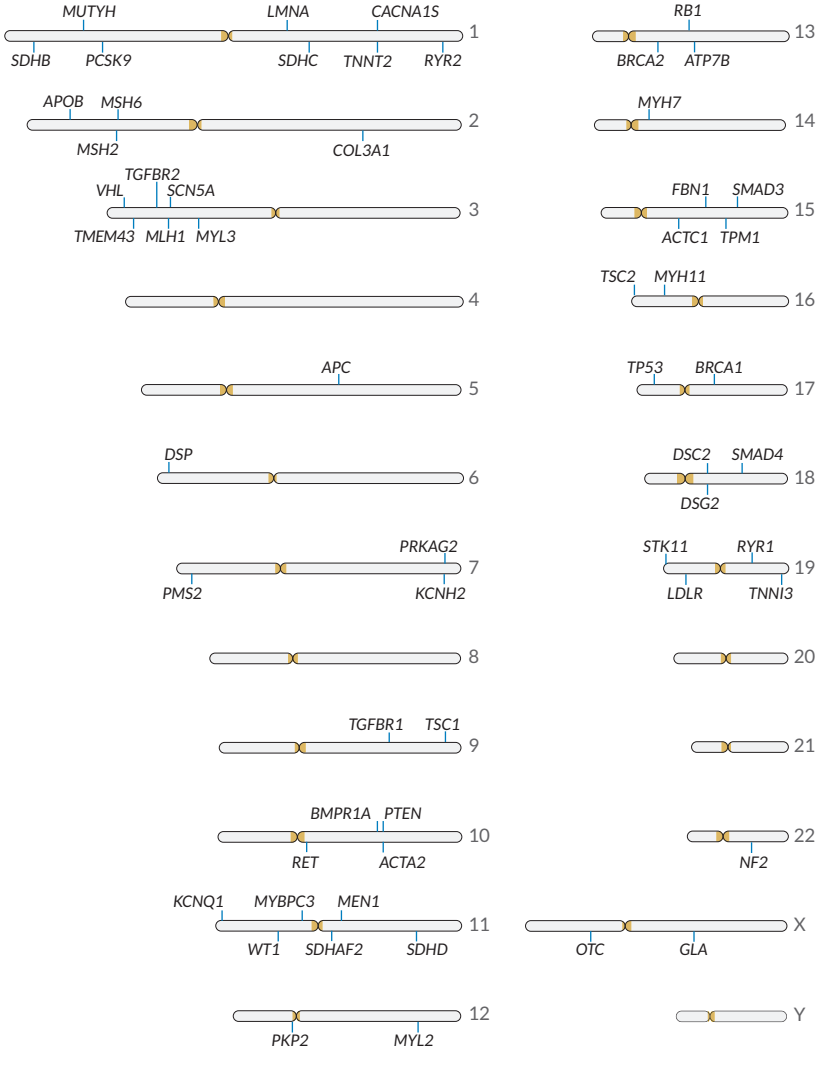
actionable." In other words, the genetic variants could cause problems for which medications, screening or other steps can be taken to ease or head off symptoms and serious consequences.

To get results on most of those medically important variants, according to U.S. Food and Drug Administration rules, a person needs a doctor to sign off, which is why Veritas requires a doctor's order before it will analyze a DNA sample.

Last year, the FDA opened the door a crack for one direct-to-consumer company, 23andMe, to offer customers information about diseases related to particular changes in individual genes — no prescription or referral needed. For example, the company can now tell customers whether they have one of three variants in the *BRCA1* and *BRCA2* genes that raise the risk of breast cancer. (There are thousands of variants in those genes linked to breast cancer, but the company is allowed to report on only three.)

Customers who want to know can also find out if they have a variant of the *APOE* gene linked to a higher chance of getting Alzheimer's disease, or variants in the *LRRK2* and *GBA* genes associated with Parkinson's disease. The company can also tell you about genetic variants that increase the risk of the eye disease macular degeneration, as well as celiac disease and some other health conditions with well-established genetic connections. All without a referral or prescription.

The list The American College of Medical Genetics and Genomics suggests that laboratories tell customers who get tested about harmful variants in 59 genes (see *BRCA1* on chromosome 17 and *BRCA2* on chromosome 13, below). With a heads-up that they have such variants, people can take action by, for example, getting more frequent screening. SOURCES: S. KALIA *ET AL/GENETICS IN MEDICINE* 2017, GENETICS HOME REFERENCE



Carried away

People inherit two copies of most genes — one from mom, one from dad. Many of the variants on the list of 59 genes cause trouble when just a single copy is inherited from one parent. Geneticists refer to such genetic variants as "dominant."

Some dominant variants lead to rare conditions, including changes in the *BRCA1* and *BRCA2* genes that can cause breast and ovarian cancers, a variant of the *PCSK9* gene that causes high cholesterol and changes in multiple genes that increase colon cancer risk. Some genetic variants linked to certain heart problems, neurological disorders and other serious health issues are also on the list.

Most people, including me, probably don't have defects in single genes that could bring on a health crisis. What we pass on to our children, though, is another matter. Many people carry one copy of a disease-causing mutation, which isn't enough to cause trouble for them, but they could pass it on to their children. A child who inherits disease-causing versions of the same gene from both parents could be very sick. That's the case for conditions such as cystic fibrosis, phenylketonuria, Tay-Sachs and many other "recessive" genetic diseases.

23andMe, Veritas and other direct-to-consumer genetic testing companies can now give information about a person's "carrier status," identifying whether you have one copy of a recessive disease variant that your kids could inherit.

Preliminary studies suggest that, on average, most people are carriers for two recessive genetic diseases — some carry no such variants, others have up to seven or eight. I'm average. I carry two, or three, depending on the company doing the test; I didn't get the same results from every company.

Being a carrier for a life-threatening genetic disease could influence a person's decisions about

E. OTWELL

having children. When both members of a couple carry disease-causing variants in the same gene, the couple has a 25 percent chance of having an affected child. Some couples might risk it; others might forgo having children. Some may try to improve their odds of having a healthy baby by seeking help from fertility clinics, where doctors can perform in vitro fertilization and then screen out embryos that have inherited two copies of the disease-causing variant (*SN: 12/23/17, p. 21*).

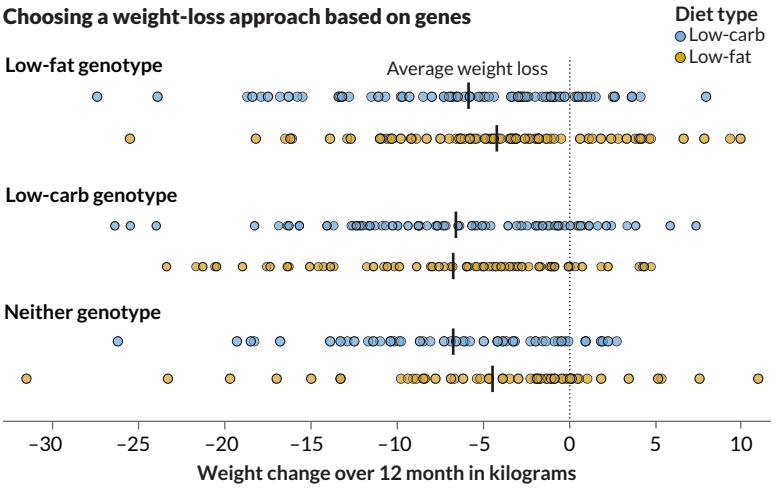
Reality check

Unlike the rare single-gene diseases, the vast majority of common traits, diseases and conditions are the product of tweaks in many genes working together. Such conditions are called polygenic traits. Researchers aren't yet very good at figuring out how all the subtle tweaks in the genome, called single nucleotide polymorphisms, or SNPs, come together to affect appearance, behavior and health.

Take type 2 diabetes, for instance. Hundreds of gene variants have been linked to the disease, but none is the single factor that ensures a person will develop the disorder. Most SNPs have only a tiny influence on the chance a person will get a disease — lifestyle and environment play a role, too.

And what should a person do about a variant that nudges up diabetes risk? Biesecker told me how it might play out. "If I do have that variant, I can go to my doctor [who] will tell me I can improve my health by improving my diet and exercising," he says. "If I don't have that variant, I can go to my doctor and my doctor will say, 'You can improve your health and longevity by improving your diet and exercising.' " If you get the same advice either way, there's little value in knowing whether you have the variant or not, he says.

Companies such as 23andMe used to tell consumers their risk of developing polygenic diseases. No more. In 2013, the FDA banned the company from giving customers in the United States that information. Right now, Veritas, which is certified to give clinical information, doesn't report risk of diseases that are influenced by multiple genes. It and other companies are allowed to tell customers about polygenic traits that aren't disease-related, such as hair and eye color or attached or detached earlobes. 23andMe examines 32 variants to weigh in on whether your earlobes hang free or cling to the side of your head. And as many as 49 different spots in the genome could be involved in earlobe shape, a study published last year in the *American Journal of Human Genetics* suggests. That study included data collected from 23andMe customers. This kind of information lands on the fun-but-frivolous end of the information spectrum. But it's kind of cool to learn the genetics behind your ear shape.



No help Participants in a weight-loss study dropped similar amounts of weight on either low-carb or low-fat diets regardless of whether variants in three genes suggested one of the diet strategies would be better. SOURCE: C. GARDNER *ET AL/JAMA* 2018

Plenty of companies claim they can read your genes to tell you what you should eat or how you should exercise. Basing your diet on science seems like the smart thing to do. But Christopher Gardner, director of nutrition studies at Stanford University's Prevention Research Center, says no. "Not today."

Gardner should know. He and colleagues tested whether variants in three genes involved in fat or carbohydrate metabolism could predict whether a person would be more successful at losing weight on a low-fat or a low-carb diet. The idea was based on his team's previous study of 130 people. Those whose genetic profile matched the diet they were assigned to lost three times as much weight as those whose diets and genetics didn't match.

"It was plausible," Gardner says. So the team expanded the study to more than 600 overweight and obese people, assigning each person at random to either a low-fat or low-carb diet. After one year, the researchers looked at weight loss among participants: Did a diet based on an individual's genetics make a difference?

"The punch line is really short," Gardner says. "It didn't work." On average, participants in both diet groups lost about five or six kilograms (12 to 13 pounds) over 12 months. Some lost much more, some less and some gained weight. But there was no connection between successful weight loss

12
million
Estimated number of people since 2007 who have gotten consumer genetic testing

7
million
Estimated number who, in 2017 alone, got consumer genetic testing — more than all previous years combined

E. OTWELL

and whether the participants' diet and gene profiles matched, Gardner and colleagues reported in the Feb. 20 *JAMA*.

I pointed out that consumer genetic companies usually include the variants Gardner and colleagues tested, plus four or five other variants related to body mass index, having a sweet tooth and sensitivity to insulin, the hormone that regulates blood sugar. Would that be better?

"No," Gardner says. "You can make a plausible claim, but then you have to test it."

Obesity is a complex trait. Studies have linked more than 200 variants to body weight, but none tell the whole story of why people's weight varies so much. "It isn't that there's one answer and in 10 years [we'll have it]," Gardner says. "The answers will get progressively clearer and clearer. We could have a couple next year. They just won't be the end-all, be-all answers."

Drug reactions

If genetic testing can't tell you much about health, diet and exercise, what is it good for? Even the most skeptical researchers I talked with said that one area holds promise: pharmacogenetics, or how variants in DNA affect how people will react to certain drugs.

David Bick, a clinical geneticist at the HudsonAlpha Institute for Biotechnology in Huntsville, Ala., has sequenced 45 people's genomes as part of a new program. The mostly white, highly educated, middle-aged participants, ranging in age from 31 to 89, paid about $7,000 for thorough physical exams along with DNA sequencing and analysis. HudsonAlpha collaborates with Huntsville-based Kailos Genetics to give participants pharmacogenetic rundowns. These drug reaction profiles will be invaluable for future reference, Bick says.

Saey didn't learn much about her health, but she did connect with relatives she didn't know. More on that in June.

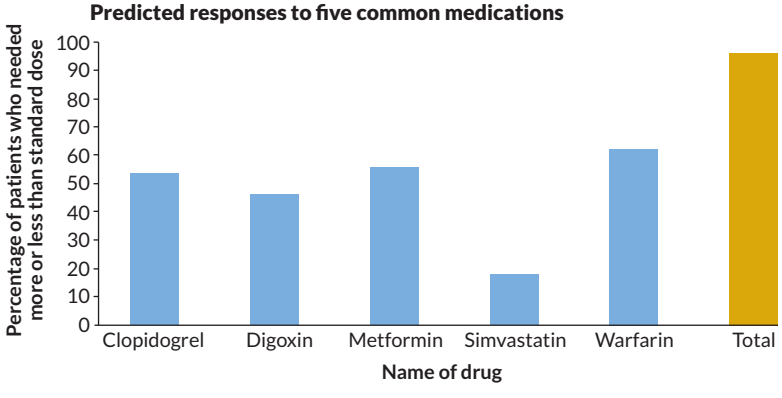
For example, doctors often prescribe a drug called clopidogrel, brand name Plavix, to people who have survived a heart attack. The drug keeps blood clots from forming, reducing the risk of another heart attack. In the body, the drug has to be converted to an active form by several enzymes, including CYP2C19. "If you have a change in that *CYP2C19* gene, you can't convert [Plavix] to the active form," Bick says. If you have a heart attack and your doctor knows you have the variant, you could get a different medication that works for you, he explains.

We all have about an 80 percent chance of having at least one genetic variant in one of 806 genes that could alter the way one of the top 100 prescribed drugs in the United States works, researchers reported December 22 in *Genome Medicine*.

Based on my Veritas report, the only one that gave this information, I have at least 48 variants that can influence my reaction to dozens of drugs, all but one of which I don't take. So the information isn't that useful right now, but it may be useful in the future.

Maybe it isn't so helpful today, but don't dismiss genetic testing out of hand, says Robert Green, a geneticist who has been studying people's responses to genetic information for more than two decades. Green, of Brigham and Women's Hospital in Boston, thinks scientists will soon have a better handle on genetic information. "What we see today is not the endgame. It's not even the second inning." ■

Dose depends Fifty patients in one study were tested for certain gene variants predicted to affect ideal drug dosing. The blue bars show the percentage of people who, based on their genes, would need a higher or lower dose than usual of a specific drug. The gold bar shows the high percentage of people predicted to need a different dose of at least one of those five common drugs. SOURCE: J.L. VASSY *ET AL/ANNALS OF INTERNAL MEDICINE* 2017



Explore more

- Genetics Home Reference. "What are the different ways in which a genetic condition can be inherited?" bit.ly/GeneDiffs

MATTHEW RAKOLA

GEOLOGIC ROAD TRIP OF THE MONTH

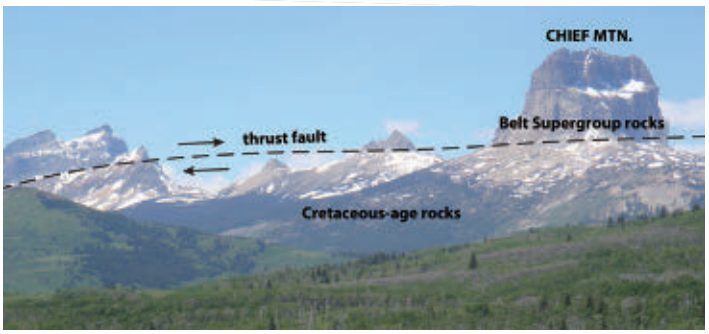
CHIEF MOUNTAIN, MONTANA

The high prairie of northern Montana rolls westward in an unfolding panorama of speckled sage and open sky, defined by a slowly rising but otherwise benign landscape. Along Montana 17 a few miles southeast of the Canadian border, topographic change is finally realized by the haughty appearance of Chief Mountain, a sentinel that identifies the Rocky Mountain Front, the eastern border of Glacier National Park, and the location of one of the world's classic—albeit enigmatic—geologic structures.

A model klippe—an outcrop isolated by faulting and erosion—standing 9,006 feet high with 1,500 feet of relief, Chief Mountain is constructed of sedimentary rocks that are of a different age and environment than the rocks of the underlying terrain. A well drilled from the mountain's crest would first engage 1,300-million-year-old green shale of the Appekunny Formation and then 1,450-million-year-old tan and red strata of the Altyn limestone. These two formations make up a significant portion of the Belt Supergroup, perhaps the best-preserved sequence of middle Proterozoic–age rock in the world. Close examination of these layers uncovers beautifully preserved ripple marks, mud cracks, raindrop impressions, and fossils of several species of algae. The fossils and preserved sedimentary features are evidence that the strata were deposited in both playa and perennial lake-basin environments that periodically were connected to the open ocean. Finally, the drill bit would penetrate sandstone and shale beds deposited under marine conditions a mere 100 million years ago, during the Cretaceous period.

The enigma of Chief Mountain has nothing to do with either the different depositional conditions or the 1,350-million-year age difference between these two suites of rocks. Instead, it is the age relationship of these juxtaposed formations. In Chief Mountain, ancient rocks overlie much younger strata, contrary to the logic of a basic geologic axiom. As mentioned in the introduction, according to the principle of superposition, in an undisturbed sequence of strata the oldest beds are positioned on the bottom. How is this deviation from the venerated principle explained?

Answers became available when geologists recognized that the northern Rocky Mountain terrain is composed of thick sequences of faulted and stacked sedimentary rocks. The nature of the faults suggests that as the forces compressing the crust in this region increased in intensity, the faults became overthrusted upon each other, much like the arrangement of cedar shakes covering a roof. This fracturing and subsequent stacking of strata effectively reversed the age relationship of the rocks—older rocks were placed over younger ones.



At Chief Mountain, limestone and shale formations of the Proterozoic-age Belt Supergroup overly much younger Cretaceous-age rocks, a textbook example of a thrust fault. Arrows indicate relative rock movement along the fault plane.

The rocks of Chief Mountain were thrust up and over younger rocks sometime between 170 million years ago, during the construction of the ancestral Rocky Mountains, and 70 million years ago, when the modern Rocky Mountains were forming. During this 100-million-year time frame the Lewis Overthrust slab formed. Measuring 200 miles long and more than 2 miles thick, this massive slab of rock was transported eastward an amazing 50 miles along one of the largest thrust faults in the world. Since then, erosion has altered the slab so that today Chief Mountain stands completely isolated—but no longer an enigma.

Because the chapter and verse of its geologic history are so beautifully preserved, the Chief Mountain klippe is widely recognized as an ancient and revealing window through which the process of modern mountain building, such as that underway today in the Himalaya Range of southern Asia, can be better understood.

Though it has gone by many names, including Kings Peak and Tower Mountain, Chief Mountain was derived from the Blackfeet Indians' name for this peak.

EXPERIENCES

Is more better? Lessons learned from genetic testing

Direct-to-consumer genetic testing first came on the market about a decade ago, but I resisted the temptation to see what health information is hidden in my DNA — until now.

As a molecular biology writer, I've been skeptical that the field of genetics is mature enough to accurately predict health (see Page 20). What finally motivated me to send away my DNA in the mail was the fact that companies are now offering much more genetic information. Is more better? Would an expensive test that deciphered my entire genetic instruction manual, or genome, reveal more about me than more limited tests? That's what I wanted to find out.

For health testing, I sent spit samples to 23andMe, Genos and Veritas Genetics, three companies that represent the various levels of DNA testing available to consumers. (I did ancestry testing, too; you can read about my experiences with that in the June 23 issue). These companies all analyze natural spelling variations in the string of letters that make up DNA. Where most people have, say, a "G," some might have an "A." Most of these genetic variants are harmless, but some raise the risk for certain diseases. Where these companies differ is in how much of the genome they assess and whether they look for only a limited set of known variants or can uncover new ones specific to an individual. — *Tina Hesman Saey*

Getting started

The DNA-testing process starts off the same for all of the companies I tried: ordering a kit online. Genos and Veritas both require a doctor to sign off on the test. 23andMe doesn't, and as a result, the U.S. Food and Drug Administration limits the medical information the company can report. My doctor reluctantly agreed, but only because I was exploring DNA testing as part of my job. She said there was nothing in my personal health records or family history that would normally lead her to order a genetic test.

The kits all contained the same type of saliva-collection tubes. Sample prep was easy — register the kit's number online, spit in a tube, mail in the sample. I also opted to let each company use my DNA in research studies, which required an extra step of answering a questionnaire about myself.

Within a couple of months, 23andMe and Genos emailed to tell me my results were available online. Because of a technical glitch, it took about seven months to get results from Veritas. The company says the typical wait time is closer to 12 weeks. Veritas also sent a copy of its report to my doctor.

23andMe

23andMe uses the oldest technology, called SNP genotype testing. SNPs, short for single nucleotide polymorphisms, are the spelling variations in DNA. For $199, 23andMe examines about 690,000 predetermined SNPs. That may sound like a lot, but it's only 0.01 percent of the 6 billion DNA letters in the human genome. It's the genetic equivalent of spot-checking a few letters in each chapter of *War and Peace* and trying to decipher the plot.

Still, the company can tell you interesting things about some physical and physiological traits, like cleft chins, dimples or the ability to taste bitter flavors. And 23andMe has FDA approval to report on a few health conditions linked to specific genetic variants, such as celiac disease and macular degeneration. The problem is, the company tests only a small subset of all potential SNPs. Getting a report of "variants not detected" doesn't mean you don't have any variants related to a particular medical condition. It just means you don't have the ones tested for. On the plus side, 23andMe provides clear explanations of what it does and doesn't test for, and lists other factors that contribute to disease risk. In fact, 23andMe does a far better job than Genos or Veritas of explaining what having specific genetic variants means.

Genos

Genos offers broader testing, for $499. It reads, or "sequences," every letter in a person's protein-producing genes. By deciphering this Cliffs Notes version of the genome, called the exome, Genos can theoretically find genetic changes that are unique to an individual, though the significance of these finds for health isn't always clear.

Compared with the other two services, Genos gave me the most data but the least useful information. The company found 44,225 variants in my exome and showed me how many are on each chromosome. But Genos provided information for just 4,294 of them because those variants are in ClinVar, the publicly available database that Genos draws information from.

And even for these variants, Genos gave few details — like how common the variants are and whether they change one of my proteins. The company offered almost no interpretation of what the variants mean for my health, other than to classify how harmful they might be: pathogenic, likely pathogenic, likely benign, benign or unknown significance. Most frustrating, Genos didn't tell me which diseases these variants are associated with. I would need to explore the scientific literature myself to figure this out. So for most people, Genos' report wouldn't be that useful.

PEART/SHUTTERSTOCK

Which test is right for you? *Science News* reporter Tina Hesman Saey tried out several DNA-testing companies to see what she would learn about her health. Here's how the companies compare.

		23andMe	Genos	Veritas Genetics
Service provided		SNP genotype testing	Exome sequencing	Whole genome sequencing
Saey's wait time		Four weeks	Nine weeks	Seven months*
Cost		$199	$499	$999
Requires a doctor's order			✓	✓
Opt-in for research		✓	✓	✓
Allows download of raw data		✓	✓	For $99
Provides information on:	Physical and behavioral traits	✓	✓	✓
	Health	✓		✓
	Carrier status	✓		✓
	Drug-gene interactions			✓
Pros		Explains results well	Provides the most raw information	Offers the most health information; can find variants linked to gene regulation
Cons		Examines a limited set of variants; DNA may need to be retested as new genetic discoveries are made	Provides little to no interpretation of findings	Reports only the findings that the company considers medically relevant

**Not typical*

The company did, however, have more to say about how my variants influence a variety of my traits, such as hair and eye color, freckling, several characteristics of my ears and my ability to smell cut grass, roses and sweat. Genos also reports how genetics can affect a few behavioral characteristics, such as a tendency to overeat and the propensity to worry.

Veritas Genetics

Finally, Veritas charged $999 to read nearly every letter in my genome, including portions in between genes that regulate gene activity and parts containing noncoding RNAs, which do a variety of cellular jobs. Those sections between genes are proving to be lush territory for discovering health risks.

Not surprisingly, Veritas gave me the most wide-ranging report. For instance, only Veritas shared "pharmacogenomic" information — how my genetic variants could influence how certain drugs affect me. The list of drugs my genes may or may not play well with is long. I take only one drug on the list, but I'm glad to have all of this information in case it becomes relevant in the future.

While Veritas has nearly the entirety of my genetic information in its data banks, the company told me surprisingly little. Turns out, I'm just not that interesting, genetically speaking. The company screened more than 40,000 genes (including the noncoding RNAs) but found no big health risks — at least, none that scientists can reliably predict today.

The company did cover a more extensive list of physical and physiological traits than either Genos or 23andMe did. Veritas' focus is on medically relevant information, though, so the traits tended to be practical: for instance, how prone someone might be to tendon injuries, how muscles would respond to exercise, and how one's genes might affect blood sugar and cholesterol levels.

Final assessment

One thing I discovered from all this testing is that the companies don't necessarily tell you everything they find in your DNA. Veritas, for instance, sometimes doesn't report certain information that it doesn't consider medically relevant. But that decision could have medical consequences.

I learned from 23andMe, for example, that I carry a variant linked to hemochromatosis, a disorder in which excess iron in the blood can build up and damage organs. My variant is unlikely to cause me harm, but it could be a problem for any future children if they also inherited a different harmful variant of the gene from their father. So that's useful information to have if planning a family. (And indeed, my husband carries this variant, though the odds of us having a child with this disorder are still low.) My Veritas report did not mention the variant. When I checked with the company, Veritas said it chose not to report this variant because of its low likelihood of causing me trouble. But I would prefer to have that information.

Overall, none of these genetic testing companies give you complete information about your health and genetics. Veritas may give you the most bang for your health care dollar, but its report is definitely not as user-friendly as 23andMe's. Unless you're a hard-core genetics nerd like me, Genos in its current form could be a frustrating experience.

Before you decide to get your DNA tested for medical reasons, talk to a genetic counselor to see which level of sequencing best suits your needs. If testing uncovers something worrisome, the result should be confirmed by a doctor. Keep in mind that genetics is an inexact science. Someday it will be better. If you can wait for that day, you may have a more satisfying experience. If you just can't wait, take the results with a grain of salt and keep an open mind. As scientists learn more, interpretations may change. ■

SOCIETY NAMES 50 ADVOCATES TO MENTOR UNDERSERVED STUDENTS

Society for Science & the Public is excited to announce this year's 50 Advocates — educators, scientists and mentors — who will help underrepresented students find opportunities to participate and compete in science research competitions and will help inspire the students to engage in STEM fields.

Each Advocate will mentor a cohort of at least three students and help them navigate the often complicated process of entering science research competitions. The Advocates will support the students as they complete research projects and apply to compete in science fairs and contests.

LEARN MORE about the Advocate Grant Program at **www.societyforscience.org/advocate-grant**

2018–2019 Lead Advocates, who will mentor groups of Advocates:

Laurel Bingman, Houston, Texas
Charmain Brammer, St. George, Utah
Jennifer Claudio, San Jose, California
Priscilla Lumbreras, Granbury, Texas
Douglas Masterson, Hattiesburg, Mississippi
Elizabeth Proctor, Monticello, Georgia
Brenda Rubenstein, Providence, Rhode Island

2018–2019 Advocates:

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Maya Bhagat, Philadelphia, Pennsylvania
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Sunada Roberts, Harrisburg, Pennsylvania
Tracy Rumbaugh, Omaha, Nebraska
Diana Techentien, Jacksonville, Florida
Kiwanna Wade, West Helena, Arkansas
Carolyn Walling, Iowa City, Iowa

MARCH 31, 2018

Tardigrade toilet humor

Eggs covered in streamerlike structures helped researchers identify a new tardigrade species, **Susan Milius** reported in "Tardigrade lays eggs covered with doodads" (*SN: 3/31/18, p. 5*). When the team looked at the critter under a microscope, the scientists also saw the tardigrade excrete a green poop about the size of the animal's body (shown below). The event, rarely caught on film, had YouTube viewer **Kimani Powell** musing about tardigrade diets: "What do they eat again? Green eggs and ham?"

KAZUHARU ARAKAWA

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Jazzed by Jupiter

Polar cyclones, a surprisingly deep atmosphere and a spin reminiscent of solid masses are among the latest discoveries the Juno spacecraft has made as it orbits Jupiter, ***Christopher Crockett*** *reported in "Juno beams back 4 Jupiter surprises"* (SN: 3/31/18, p. 10).

The findings astonished readers on Reddit.

"Jupiter is one of those things [that] makes me sad that I'll die never truly understanding the magnitude of what is going on there," Reddit user **Cornpwns** wrote. "I would love to be in an invincibility bubble flying through Jupiter."

Reddit user **diggitydiggitydank** wondered how gas planets such as Jupiter, which may not have a solid core (*SN: 6/24/17, p. 14*), could have formed in the early solar system.

Jupiter's birth is still debated, but scientists have a few basic ideas, *Science News* astronomy writer **Lisa Grossman** says. One theory is that relatively small rocks may have collided about 4.5 billion years ago to form a larger rocky core — a process called pebble accretion. That core would have had enough gravity to start gathering lots of gas fairly quickly. "Poof! You have a Jupiter," **Grossman** says.

But there are unanswered questions about the pebble accretion model, she says. "How did the pebbles glom together? Why didn't they just bounce off of each other? And if Jupiter doesn't have a core now, where did the core go?"

Another theory is that Jupiter could have formed directly from gas in the protoplanetary disk of gas and dust that surrounded the infant sun. Regions of the disk could have become so massive that gas collapsed to form giant planets. If true, "that would explain why Jupiter wouldn't have a core," **Grossman** says.

Going viral

Scientists are finding more and more large viruses with giant genomes, ***Emily DeMarco*** *reported in "Viruses go big"* (SN: 3/31/18, p. 32).

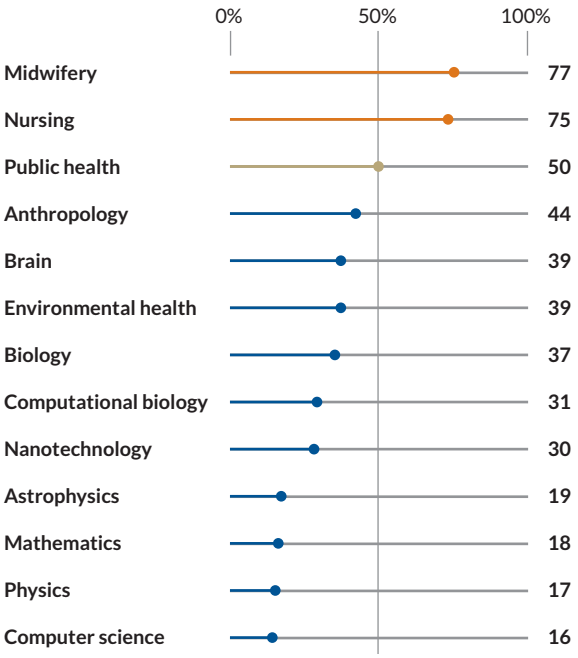
Facebook user **Har Mahdeem** thought that viruses should be recognized as a new kingdom on the tree of life.

For decades, the debate over whether viruses are alive has ebbed and flowed (*SN: 4/2/38, p. 221*). Many biologists have dismissed viruses as nonliving, in part, because viruses can't reproduce on their own and typically lack much of the genetic complexity of life-forms. Recent discoveries of giant viruses and their genetic hoards continue to fuel these debates (*SN Online: 2/27/18*).

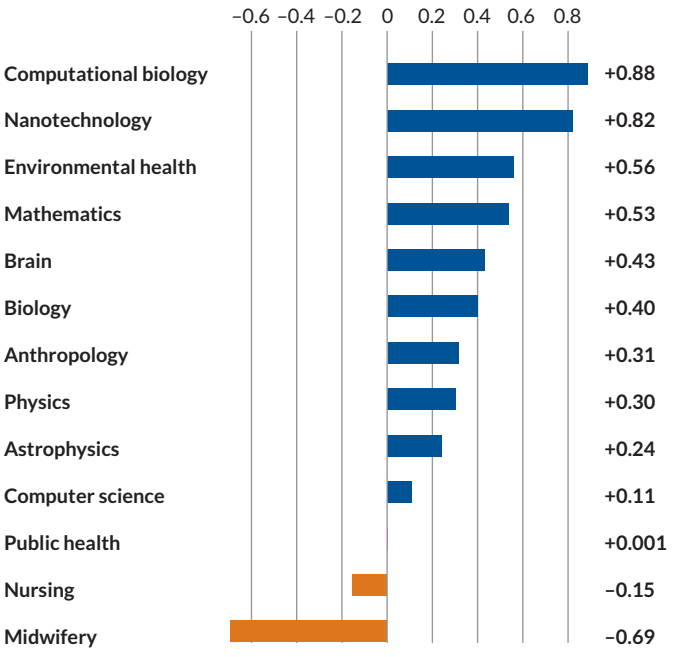
Viruses are not currently included on the tree of life. But the tree is undergoing a tumultuous revision — kingdoms that used to crown the top have become branchlets within much larger supergroups (*SN: 8/8/15, p. 22*). Putting viruses in a plausible place on this emerging tree would require tracing ancient branches to work out any viral connections to unambiguous life. It would be a huge challenge, says *Science News* life sciences writer **Susan Milius**.

Female-dominated field Male-dominated field At parity

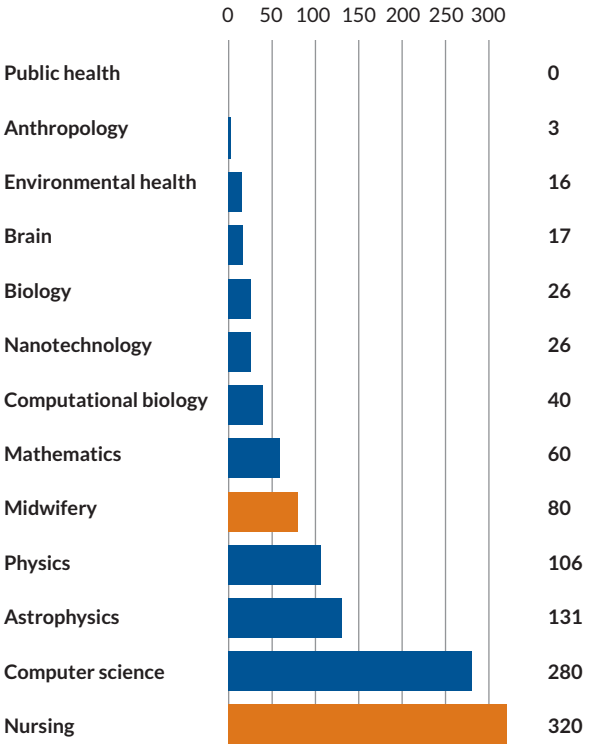
Percentage of female authors in 2016, for select disciplines



Current rate of change in percentage of female authors per year



Predicted years until the gender gap disappears



How long until the gender gaps in science disappear?

If you're a female computer scientist, you may not see an equal number of men and women working in your field in this century — or even the next one. A study, reported April 19 in *PLOS Biology*, predicts when the gender gap will close for a number of science-related fields.

In their analysis, researchers from the University of Melbourne in Australia compiled the overall numbers of men and women authors listed on more than 10 million academic papers in nearly 5,000 academic journals and about 120 arXiv.org subcategories, published from 2002 to 2016.

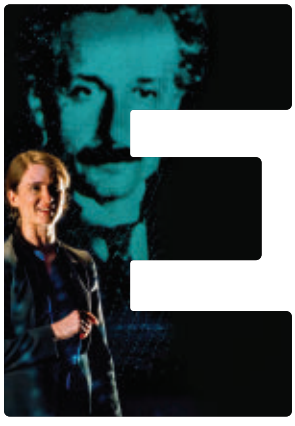
Then, the scientists categorized the journals by field and estimated the percentage of female authors in 2016 in each (top left; a selection of fields shown), the field's current rate of change per year (top right) and the years until the gender gap is predicted to close (left). The number of women authoring research papers is a reliable predictor of the number of women working in each field, the team argues.

In public health, men and women are already represented in roughly equal numbers. But in most other fields, male authors outnumber females. Women exceed men in a few, such as nursing and midwifery (orange bars). Computer science, though, has the lowest proportion of women authors and, apart from nursing, would take the longest to reach gender parity. — *Kyle Plantz*

CHARTS: C. CHANG; DATA: L. HOLMAN *ET AL*/*PLOS BIOLOGY* 2018

RETHINK SCIENCE

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